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6 **Test Methodology and Ballistic Testing**

of an

Experimental Aircraft Passive Defense

Armor System.

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10 **Abraham A. Santiago, Jr. 1st Lt, USAF**

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FOREWORD

This program was conducted under Project 2549-01, Terminal Effects Versus Air Targets, and Armament Development and Test Center (ADTC) Test No. [illegible]001, Small Arms Firings Versus Aircraft Components. The work was performed in support of Air Force Flight Dynamics Laboratory (AFFDL) Task 142503, Passive Defense Provisions for Personnel Protection, from October 1968 to March 1969.

The guidance and assistance provided by Messrs. George W. Ducker and Michael R. Gromosiak of AFFDL are acknowledged. The excellent performance of munitions and electronics personnel of the Damage Mechanisms Branch (DLMD) is also appreciated. Acknowledgement is extended to Vitro personnel at Test Areas C-74 and C-74L for their outstanding support during target preparation and damage data collection.

This technical report has been reviewed and is approved.

CHARLES K. ARPKE, Lt Colonel, USAF
Chief, Weapons Effects Division

ABSTRACT

This report discusses the methodology used to conduct ballistic tests in support of an experimental armor system for the protection of aircrew members. The system was designed to protect crew members of high performance aircraft and was installed on an obsolete F-89J aircraft for destructive tests. Shots were fired with .30 caliber and .50 caliber AP-M2 and 20mm fragment simulating projectiles. Field firing records of all shots are contained in Appendix III. No analysis of the field data was made in this report.

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SECTION I

INTRODUCTION

The overall purpose of this program was to evaluate a passive defense system for fighter aircraft crew station protection. The system consists of a series of armor panels placed in selected positions around the crew station of the aircraft.

The approach used in this development program was to:

- Conduct a parametric study of the threat to typical combat aircraft.
- Prepare a design manual for crew station passive defense provisions.
- Design and construct an experimental system.
- Conduct ballistic tests on the experimental system.(1)

The first three portions of the development program were performed by the Aircraft Armament Incorporated (AAI) Corporation under contract with the Air Force Flight Dynamics Laboratory (AFFDL). The AAI Corporation also prepared the initial ballistic firing program and installed the armor on the aircraft.

This report is presented in two phases:

1. The methodology used to transform the contractor original firing program.
2. A description of the ballistic tests conducted by the Air Force Armament Laboratory in support of the Air Force Flight Dynamics Laboratory program.

An obsolete F-89J aircraft was used for these tests since it was readily available for destructive testing. The experimental system was designed to fit the F-89J and was installed in this aircraft.

SECTION II

DESCRIPTION OF EXPERIMENTAL ARMOR

The experimental armor system was composed basically of two types of armor: dual hardness steel (DHS) armor and ceramic composite armor. Both types were designed to defeat up to .50 caliber armor piercing (AP) ammunition at service velocity and normal obliquity. Panels of DHS armor were placed on the outside skin of the fuselage on both sides of the crew station [Figures 1(A) and 1(B)]. These panels were formed to fit the shape of the fuselage. Another panel of DHS armor was placed directly forward of the front cockpit instrument panel. This panel was held in place by metal fastners bolted to the floor and to the fuselage bulkhead [Figures 2(A) and 2(B)].

DHS and ceramic composite-type armor panels were placed on the floor of both cockpits, as well as on the bottom part of the side consoles.

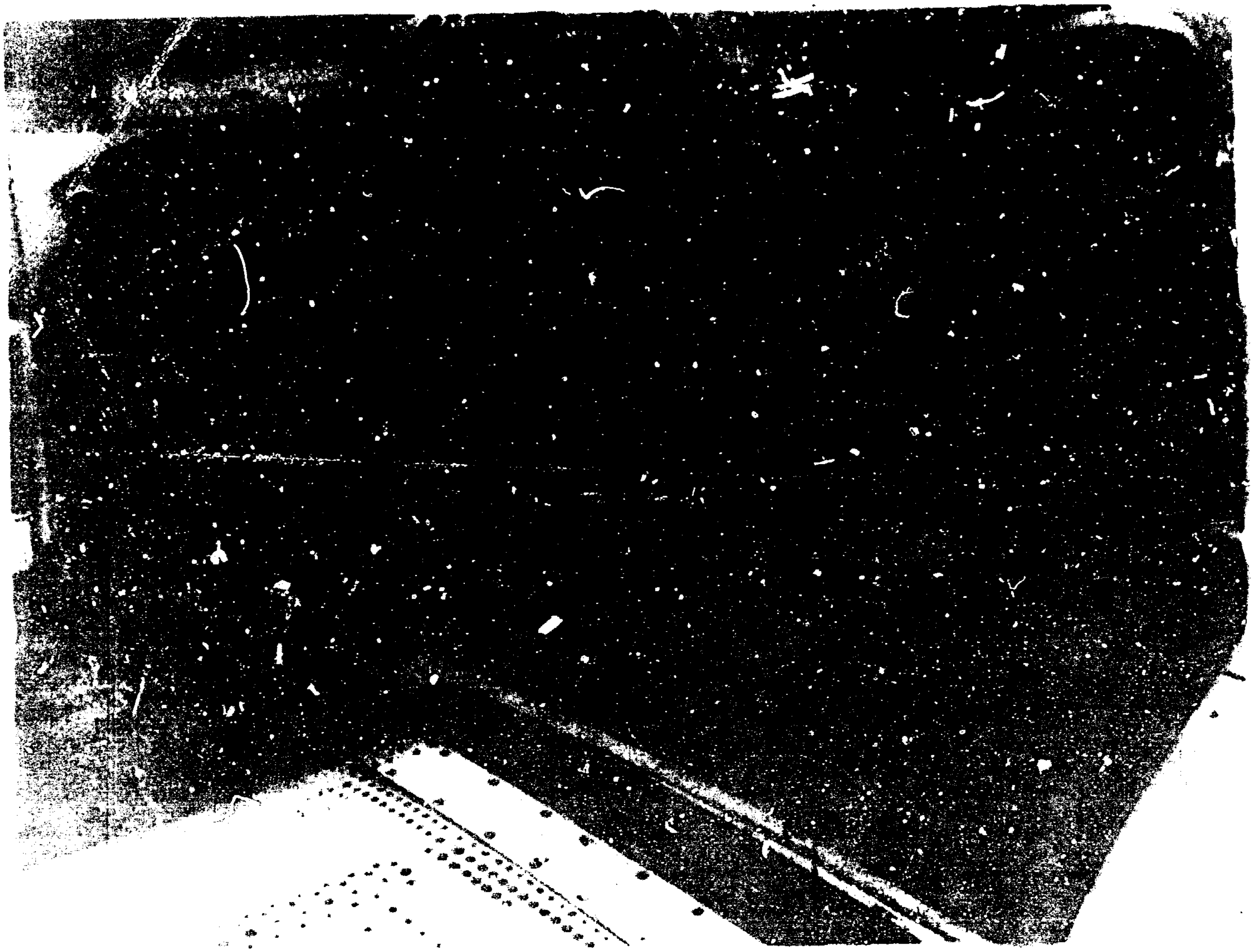

Figure 1(A). Experimental Dual Hardness Steel Armor on the Left Side of the Aircraft

Figure 1(B). Experimental Dual Hardness Steel Armor on the Right Side of the Aircraft

Figure 2(A). Metal Bracket Attached to the Dual Hardness Steel Armor Plate Behind the Front Cockpit Instrument Panel

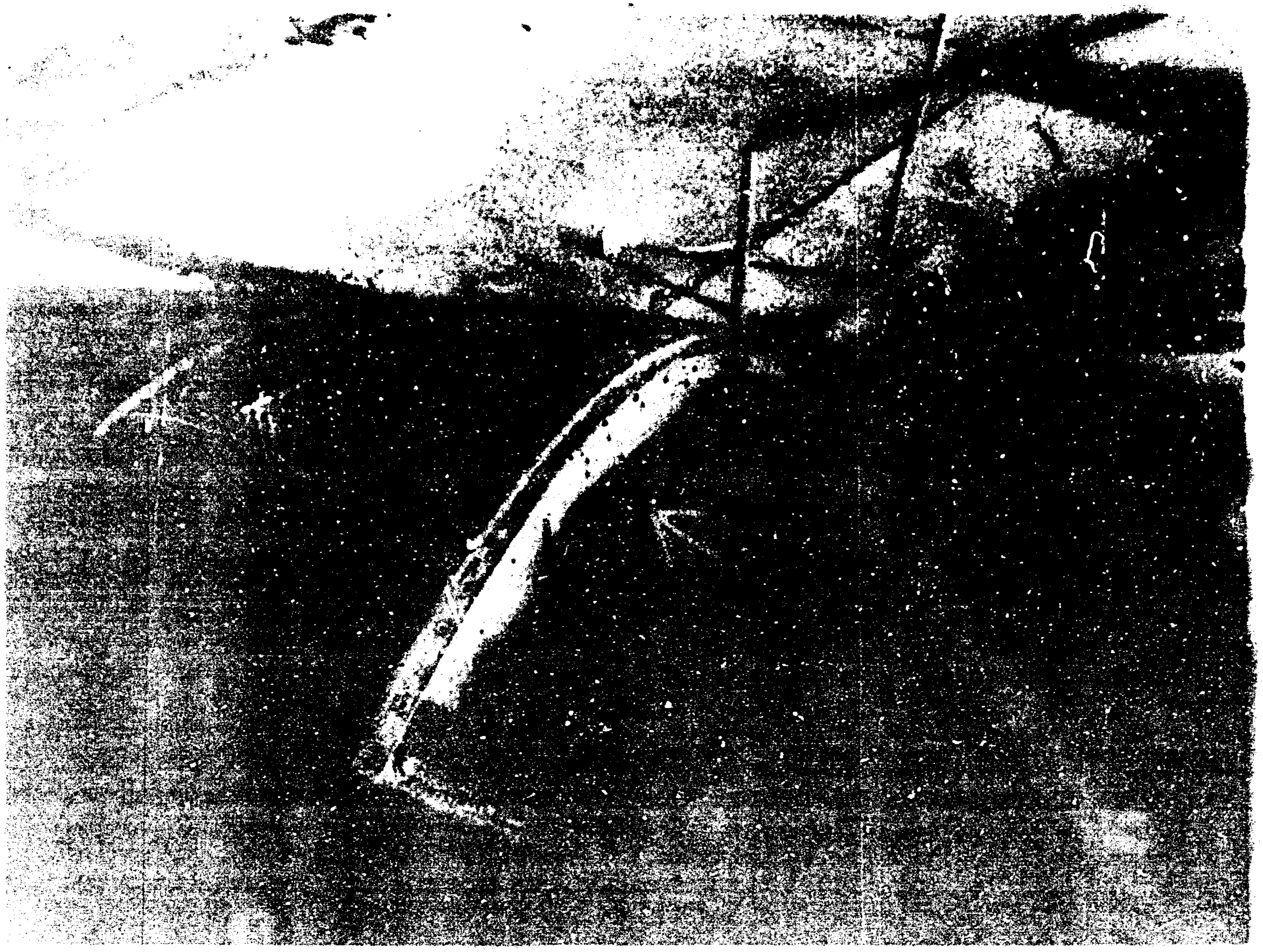

Figure 2(B). Metal Fastener Attached to the Bulkhead at Fuselage Station 143.0

SECTION III

TEST SETUP

The firing plan proposed by the AAI Corporation was designed to simulate small arms ground fire. The armored aircraft target was exposed to small arms fire from several selected attack aspect angles and impact velocities simulating actual combat conditions.

In making the selection of these test parameters, the aircraft was assumed to be traveling on level flight at a speed of 520 knots and an altitude of 200 feet. Under these conditions, the striking velocity of the projectile was calculated for each attack aspect angle, taking into consideration the projectile standard muzzle velocity, its velocity degradation with distance, and the aircraft velocity vector relative to the projectile velocity vector. Impact velocities for both .30 caliber and .50 caliber AP-M2 ammunition were calculated. In addition, several shots were fired, using 825-grain 20mm fragment simulating projectiles (FSP's) to represent explosive warhead damage. All firings with 20mm FSPs were at 3500 fps impact velocity.

A total of 48 shots was proposed in the contractor test plan, divided into 28 shots of .50 caliber, 12 shots of .30 caliber, and 8 shots of 20mm FSPs. All shots were directed toward the following four target points:

Target	Coordinates
Pilot's head	0, 215.5, 52
Pilot's torso	0, 215.5, 33
Radar operator's head	0, 267.5, 54
Radar operator's torso	0, 267.5, 36

The coordinates are expressed in inches, and the origin is the forwardmost point on the aircraft. The coordinate system is right-hand cartesian with the positive y direction form nose to tail and the positive z direction from bottom to top.

In order to specify the line of fire, the components of a vector of arbitrary length along the line of fire were defined. Figure 3 illustrates the geometry of the problem. The point F represents the target point (any one of the four defined above). The point Pa is an arbitrary point along the line of fire. The three components of the vector $\overline{FPa}$ (ΔX, ΔY, ΔZ) are the direction numbers of the line of fire.

Table I presents the firing plan proposed by the contractor. The point P corresponds to the coordinates of the indicated target point, and the direction numbers are the components of an arbitrary vector Pa along the line of fire.

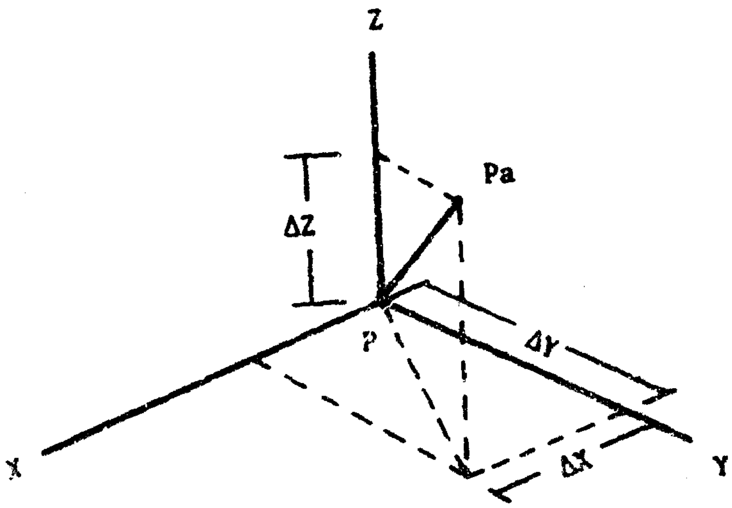

Figure 3. Geometry for the Definition of the Line of Fire

TABLE I. FIRING PLAN

TARGET POINT	SHOT NUMBER	AMMUNITION	STRIKING VELOCITY (FPS)	COORDINATES OF POINT P X	Y	Z	DIRECTION NUMBERS OF LINE OF FIRE [illegible]	[illegible]	[illegible]
Pilot's head	1	.50 Caliber AP-M2	3120	0	221	50	0	-0.721	-1
Pilot's head	2	.50 Caliber AP-M2	3450	0	221	50	+0.302	-3.731	-1
Pilot's head	3	.50 Caliber AP-M2	3420	0	221	50	+0.004	-0.9[illegible]	-1
Pilot's head	4	.50 Caliber AP-M2	3290	0	221	50	-0.054	-0.[illegible]	-1
Pilot's head	5	.50 Caliber AP-M2	3500	0	221	50	-0.162	-1.760	-1
Pilot's head	6	.50 Caliber AP-M2	3480	0	221	50	+0.4[illegible]	-2.73[illegible]	-1
Pilot's head	7	.50 Caliber AP-M2	3520	0	221	50	+0.297	-1.741	-1
Pilot's head	8	.50 Caliber AP-M2	3420	0	221	50	+0.940	-2.620	-1
Pilot's head	9	.50 Caliber AP-M2	3490	0	221	50	+0.5[illegible]	-1.646	-1
Pilot's head	10	.50 Caliber AP-M2	3410	0	221	50	+1.080	-1.801	-1
Pilot's head	11	.50 Caliber AP-M2	3320	0	221	50	+0.710	-1.251	-1
Pilot's head	12	.50 Caliber AP-M2	3230	0	221	50	+0.707	-0.707	-1
Pilot's head	13	.50 Caliber AP-M2	3170	0	221	50	+0.500	-0.500	-1
Pilot's head	14	.50 Caliber AP-M2	2820	0	221	50	+0.186	0	-1
Pilot's head	15	.50 Caliber AP-M2	3490	0	221	50	+0.378	0	-1
Radar Operator's head	16	.50 Caliber AP-M2	3440	0	285	54	+0.415	-1.111	-1
Radar Operator's head	17	.50 Caliber AP-M2	3230	0	285	54	+0.915	-0.755	-1
Radar Operator's head	18	.50 Caliber AP-M2	3040	0	285	54	+0.795	-0.209	-1
Radar Operator's head	19	.50 Caliber AP-M2	2850	0	285	54	+0.280	0	-1
Pilot's torso	20	.50 Caliber AP-M2	2900	0	218	31	+0.980	-0.238	-1
Pilot's torso	21	.50 Caliber AP-M2	2900	0	218	31	-0.980	-0.238	-1
Radar Operator's torso	22	.50 Caliber AP-M2	3280	0	282	26	+2.120	-4.380	-1
Radar Operator's torso	23	.50 Caliber AP-M2	3280	0	282	26	-2.120	-4.380	-1
Pilot's torso	24	.50 Caliber AP-M2	3230	0	218	31	+2.120	-2.100	-1
Pilot's torso	25	.50 Caliber AP-M2	3260	0	218	31	+2.362	-4.230	-1
Radar Operator's head	26	.50 Caliber AP-M2	2470	0	285	54	+0.140	+0.498	-1
Radar Operator's head	27	.50 Caliber AP-M2	2050	0	285	54	0	+1.43	-1
Radar Operator's head	28	.50 Caliber AP-M2	2220	0	285	54	+0.577	+1.11	-1
Pilot's torso	29	825-Grain FSP	3500	0	218	31	-0.755	-1.281	-1
Pilot's torso	30	825-Grain FSP	3500	0	218	31	+1.275	-0.740	-1
Pilot's torso	31	825-Grain FSP	3500	0	218	31	+0.077	+0.511	-1
Pilot's torso	32	825-Grain FSP	3500	0	218	31	+0.580	+0.[illegible]	-1

TABLE I. (CONCLUDED)

TARGET POINT	SHOT NUMBER	AMMUNITION	STRIKING VELOCITY (FPS)	COORDINATES OF POINT P			DIRECTION NUMBERS OF LINE OF FIRE		
				x	y	z	Δx	Δy	Δz
Radar Operator's head	33	825-Grain FSP	3500	0	286	54	+0.255	+1.443	-1
Pilot's head	34	825-Grain FSP	3500	0	221	50	+0.460	-2.738	-1
Pilot's head	35	825-Grain FSP	3500	0	221	50	+0.940	-2.630	-1
Pilot's head	36	825-Grain FSP	3500	0	221	50	+0.378	0	-1
Pilot's head	37	.30 Caliber AP-M2	3240	0	221	50	0	-0.721	-1
Pilot's head	38	.30 Caliber AP-M2	3240	0	221	50	0	-0.721	-1
Pilot's head	39	.30 Caliber AP-M2	3246	0	221	50	0	-0.721	-1
Pilot's head	40	.30 Caliber AP-M2	3080	0	221	50	-0.054	-0.830	-1
Pilot's head	41	.30 Caliber AP-M2	3080	0	221	50	-0.054	-0.830	-1
Pilot's head	42	.30 Caliber AP-M2	3080	0	221	50	-0.054	-0.830	-1
Pilot's head	43	.30 Caliber AP-M2	3010	0	221	50	+0.707	-0.707	-1
Pilot's head	44	.30 Caliber AP-M2	3010	0	221	50	+0.707	-0.707	-1
Pilot's head	45	.30 Caliber AP-M2	3010	0	221	50	+0.707	-0.707	-1
Pilot's torso	46	.30 Caliber AP-M2	2720	0	218	31	+0.980	-0.238	-1
Pilot's torso	47	.30 Caliber AP-M2	2720	0	218	31	+0.980	-0.238	-1
Pilot's torso	48	.30 Caliber AP-M2	2720	0	218	31	+0.980	-0.238	-1

SECTION IV

TEST METHODOLOGY

In order to establish the desired projectile trajectories, it was necessary to transform the format of the firing plan. The approach taken was to use the information in Table I to generate, for each shot, an aiming point on the skin of the aircraft and the azimuth and elevation angles of the line of fire relative to the target. In this format, the gun can be sighted on a visible aiming point, and azimuth and elevation angles can be easily measured with a transit and a theodolite-type angle gauge.

With reference to Figure 4, and using the right-hand cartesian coordinate system described in Section III of this report, the azimuth angle of a vector is the angle between the positive X-axis and the projection of the vector on the X-Y plane. The angle is considered positive when measured from X toward Y and is considered negative when measured from X toward -Y. The azimuth is identical to the angle θ as defined in spherical coordinates.

The elevation angle is the smallest angle between the X-Y plane and the vector itself. The angle is considered positive when measured from the X-Y plane toward Z and is considered negative when measured from the X-Y plane toward -Z. The vector is always positioned with the nose at the origin. The elevation angle corresponds to the angle (90 - θ) in spherical coordinates. In calculating this angle, the coordinate system in the aircraft was changed letting the X-axis go along the fuselage. The origin of the system was changed to coincide with fuselage station zero (the forward-most point of the aircraft is fuselage station -10.91). Therefore, the X-coordinates represent fuselage stations, the Y-coordinates represent wing stations, and the Z-coordinates represent water lines (all in inches). The origin (0, 0, 0) is then at fuselage station 0, water line 100, and the centerline of the aircraft (Figure 5).

Using these rules, the firing plan was transformed. The first step was to define, for each shot, the equation of the firing line in space. Then a computerized geometric model (2), (3), (4) of the F-89J aircraft was used to calculate the intersection of this line with the aircraft skin (aiming point) and the azimuth and elevation angles. Appendix I presents an explanation of the problem mathematics.

Table II presents the transformed firing plan. The impact points are expressed by fuselage stations and either water lines or wing stations (only two shots encounter the wing of the aircraft). As can be seen in Table II, all elevation angles are negative since the firing plan simulates ground fire on the aircraft in level flight. This requirement presented difficulty in positioning the aircraft and gun for firings. Following [illegible] recommendations, a limited amount of dismantling was performed

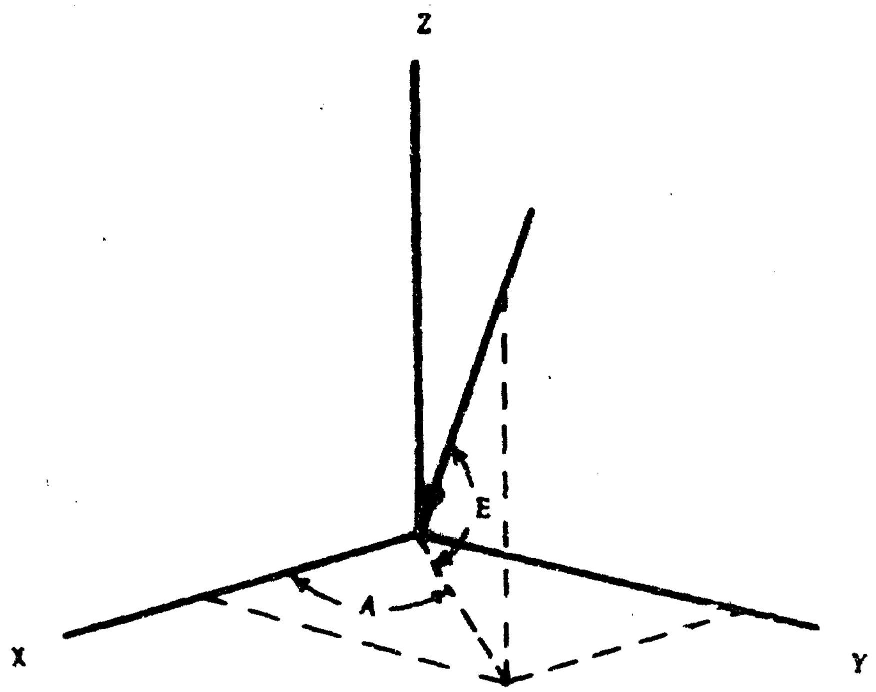

Figure 4. Definition of Azimuth and Elevation Angles

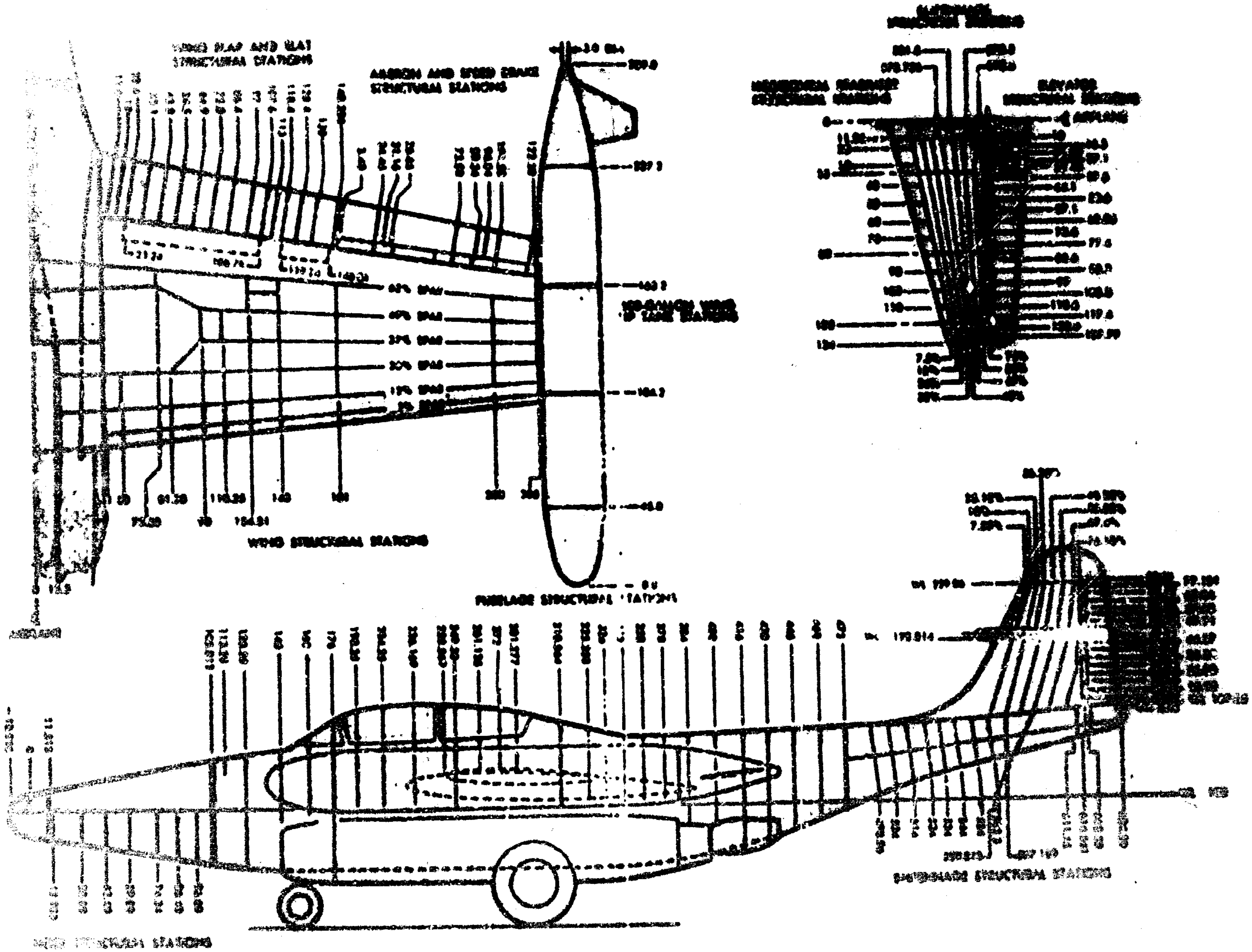

Figure 5. F-89J Stations and Frame Diagram (From T.O. 1F-89J-3-1)

TABLE II. TRANSFORMED FIRING PLAN

TARGET POINT	SHOT NUMBER	AZIMUTH	ELEVATION	FUSELAGE STATION	WATER LINE	WING STATION	AMMUNITION	STRIKING VELOCITY (FPS)
Pilot's head	1	0.0	-54.21	143.42	67.62		.50 Caliber	[illegible]
Pilot's head	2	4.63	-14.96	14.38	101.11		.50 Caliber	[illegible]
Pilot's head	3	4.86	-45.24	124.16	70.94		.50 Caliber	[illegible]
Pilot's head	4	-3.68	-40.94	134.60	69.10		.50 Caliber	[illegible]
Pilot's head	5	-5.29	-29.65	77.33	79.44		.50 Caliber	[illegible]
Pilot's head	6	9.52	-19.82	69.97	102.92		.50 Caliber	[illegible]
Pilot's head	7	9.68	-29.52	87.42	84.80		.50 Caliber	3520
Pilot's head	8	19.74	-19.76	123.93	121.34		.50 Caliber	3420
Pilot's head	9	19.70	-29.78	121.91	101.94		.50 Caliber	[illegible]
Pilot's head	10	29.73	-24.66	147.22	121.84		.50 Caliber	3410
Pilot's head	11	29.58	-34.81	147.45	106.50		.50 Caliber	[illegible]
Pilot's head	12	45.00	-45.00	168.60	101.57		.50 Caliber	[illegible]
Pilot's head	13	45.00	-54.73	163.43	70.38		.50 Caliber	3170
Pilot's head	14	90.00	-79.46	204.25	57.24		.50 Caliber	[illegible]
Pilot's head	15	90.30	-69.29	204.25	60.95		.50 Caliber	[illegible]
Radar Operator's head	16	20.48	-40.14	168.02	64.46		.50 Caliber	[illegible]
Radar Operator's head	17	50.47	-40.13	231.96	---	43.07	.50 Caliber	3230
Radar Operator's head	18	70.02	-49.77	253.18	---	39.38	.50 Caliber	3940
Radar Operator's head	19	90.00	-73.88	267.50	57.86		.50 Caliber	[illegible]
Pilot's torso	20	76.35	-44.76	193.78	89.01		.50 Caliber	[illegible]
Pilot's torso	21	-76.35	-44.76	193.78	89.01		.50 Caliber	2900
Radar Operator's torso	22	25.83	-11.61	207.32	122.26		.50 Caliber	3280
Radar Operator's torso	23	-25.83	-11.61	207.32	122.26		.50 Caliber	3280
Pilot's torso	24	45.27	-18.53	173.14	101.81		.50 Caliber	3230
Pilot's torso	25	29.18	-11.66	157.20	121.88		.50 Caliber	3260
Radar Operator's head	26	163.99	-62.96	314.19	58.32		.50 Caliber	2470
Radar Operator's head	27	180.00	-34.96	300.00	68.34		.50 Caliber	2050
Radar Operator's head	28	152.53	-38.63	346.63	82.71		.50 Caliber	2230
Pilot's torso	29	-30.36	-34.59	145.00	85.64		20mm	[illegible]
Pilot's torso	30	59.74	-34.11	183.02	104.46		20mm	[illegible]

TABLE II. (CONCLUDED)

TARGET POINT	SHOT NUMBER	AZIMUTH	ELEVATION	FUSELAGE STATION	WATER LINE	WING STATION	AMMUNITION	STRIKING VELOCITY (FPS)
Pilot's torso	31	120.23	-44.72	230.29	82.04		20mm	[illegible]
Pilot's torso	32	150.94	-44.16	268.32	61.81		20mm	[illegible]
Radar Operator's head	33	169.98	-34.31	388.41	70.21		20mm	[illegible]
Pilot's head	34	9.52	-19.82	69.96	102.92		20mm	[illegible]
Pilot's head	35	19.74	-19.76	123.96	121.35		20mm	[illegible]
Pilot's head	36	90.00	-69.29	204.25	60.96		20mm	[illegible]
Pilot's head	[illegible],38,39	[illegible].0	-54.21	143.42	67.62		.30 Caliber	[illegible]
Pilot's head	40,41,42	-3.[illegible]	-49.95	134.69	69.09		.30 Caliber	[illegible]
Pilot's head	43,44,45	45.00	-45.00	168.60	101.57		.30 Caliber	3010
Pilot's torso	46,47,48	76.35	-44.76	193.78	[illegible].01			2730

on the aircraft to permit positioning of the aircraft relative to the gun. The dismantling consisted of (1) unbolting the right wing from the fuselage (wing station 41),(2) cutting the left wing just outside the main landing gear (approximate wing station 150),and (3) cutting the empennage assembly at approximately station 493 (Figure 5). With this amount of disassembly, it was possible to select convenient positions of the aircraft and gun.

Six basic positions were selected for the aircraft. By repositioning the gun, these six positions allowed firing of all shots. The positions, expressed in terms of the angle between the section of the left wing on the aircraft and the horizontal,are 90°, 80°, 55°, 45°, -55°, and -90°. Although the azimuth orientation of the aircraft had to be changed several times to conform with range safety procedures (downrange firing), these positions allowed for a minimum of time-consuming aircraft movements.

Figures 6 through 9 show the target aircraft ready for firings in the 90° position. Due to the relatively compact shape of the aircraft after disassembly, it was found that it will actually rest in place in this position. However, sandbags were placed all around the aircraft for additional securing and safety.

Figures 10 and 11 show the aircraft in the 80° position. In this case, additional sandbags were placed under the right wing attachment section to obtain the desired angle.

The 45° position of the aircraft is illustrated in Figure 12. Again, the aircraft was secured in place with sandbags under the main fuselage.

In order to obtain the -55° position, it was necessary to dig a trench for the left-wing section of the aircraft. Figures 13, 14, and 15 show this position. Sandbags were again used to secure the aircraft in place.

The remaining 55° and 90° positions were obtained by varying the 45° and -55° positions.

Since all angles were measured relative to the horizontal plane, it was necessary to transform the firing plan in Table II again. The approach was to perform a transformation of coordinates for each position of the aircraft and to calculate the azimuth and elevation angles in relation to the coordinate system on the ground (the X-Y plane being the horizontal plane). Appendix II presents a detailed treatment of the approach used. Table III presents the final firing plan used in the test.

In addition to the transformed test program, several additional shots were fired after completion of the program. These shots were necessitated by the following observations:

1. Several shots in the firing program did not encounter any armor.

2. Several shots could not be traced through the target aircraft.

3. Most outside panels were untouched at the end of the firing program.

4. Ricochets resulted from shots with high obliquity impact angles when striking directly on armor.

Based on these observations, 21 additional tests were conducted, all at normal obliquity to the target. Test conditions were as follows:

1. .50 caliber AP at 3500 fps impact velocity directly at a panel.

2. .50 caliber AP at 3500 fps impact velocity at an attachment bolt on a panel.

3. .50 caliber AP at 3500 fps impact velocity directly at a fracture on a panel (several external panels fractured).

4. .50 caliber AP at 3500 fps followed by three shots of .30 caliber AP at 3200 fps (multiple hits) directly at a panel.

5. .50 caliber AP at 3500 fps followed by two shots of 20mm FSP at 3500 fps directly on a panel.

6. 14.5mm API at standard velocity directly on a panel.

7. 20mm HEI at standard velocity directly on a panel.

Figure 6. Target Aircraft in 90° Position, Top View

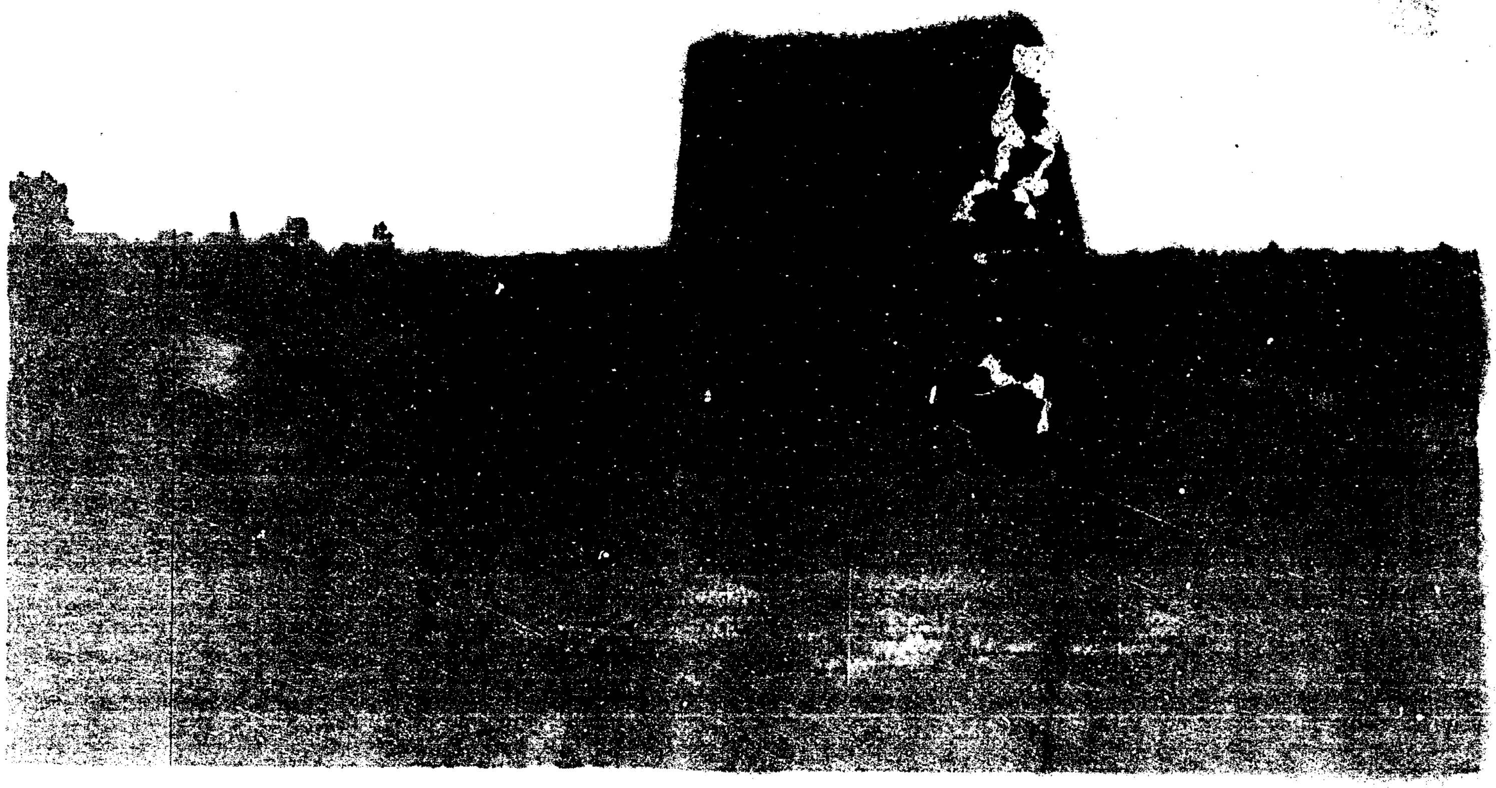

Figure 7. Target Aircraft in 90° Position, Bottom View

Figure 8. Target Aircraft in 90° Position, Front View

Figure 9. Target Aircraft in 90° Position, Rear View

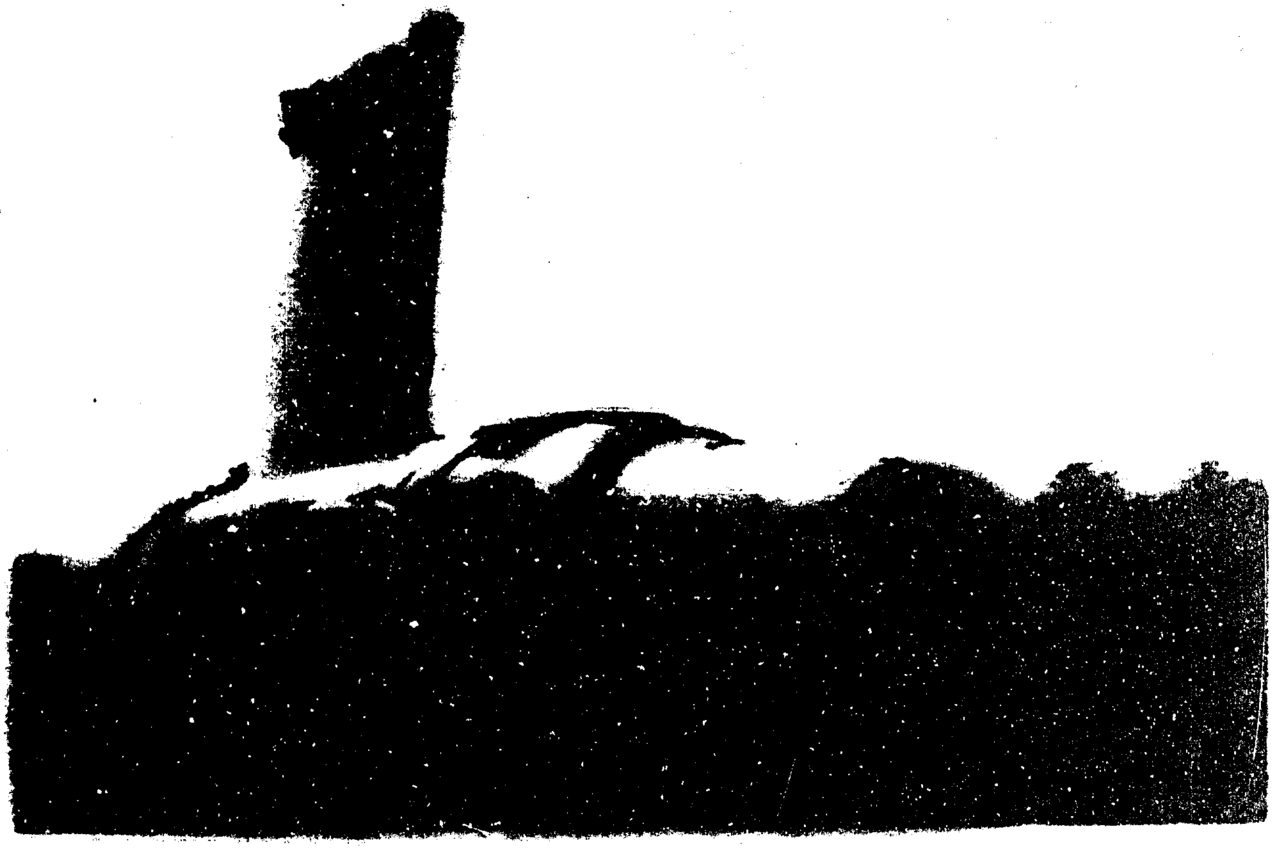

Figure 10. Target Aircraft in 20° Position, Top View

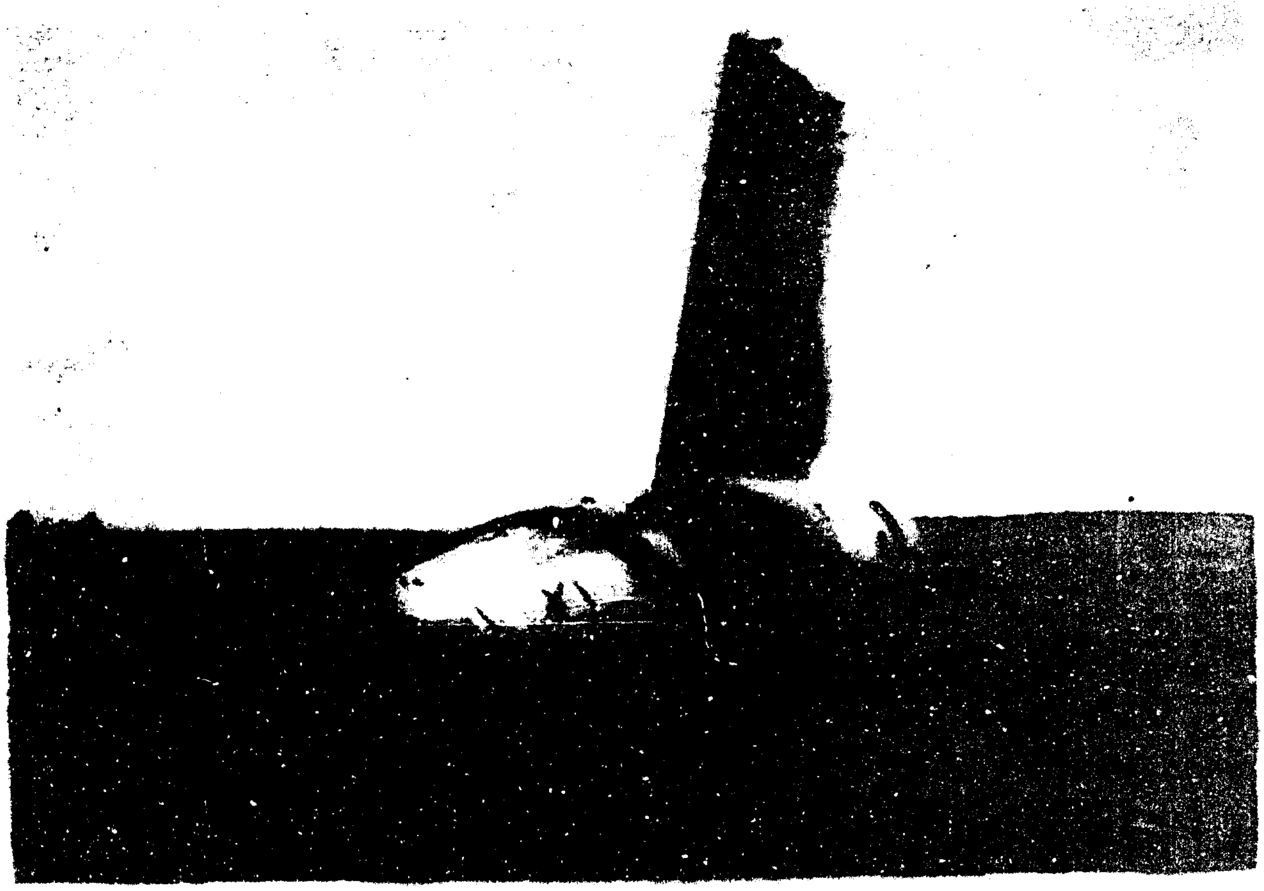

Figure 11. Target Aircraft in 80° Position, Bottom View

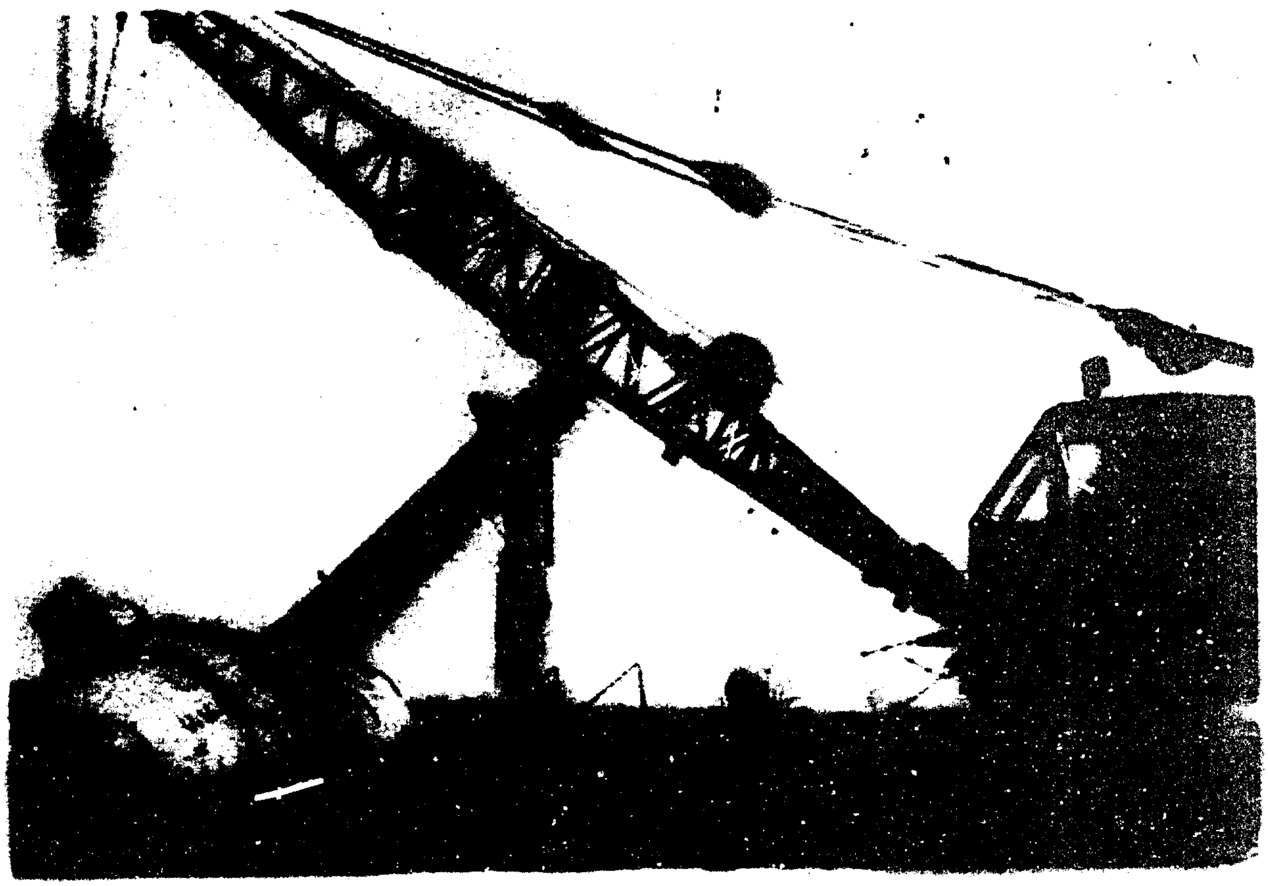

Figure 12. Target Aircraft in 45° Position

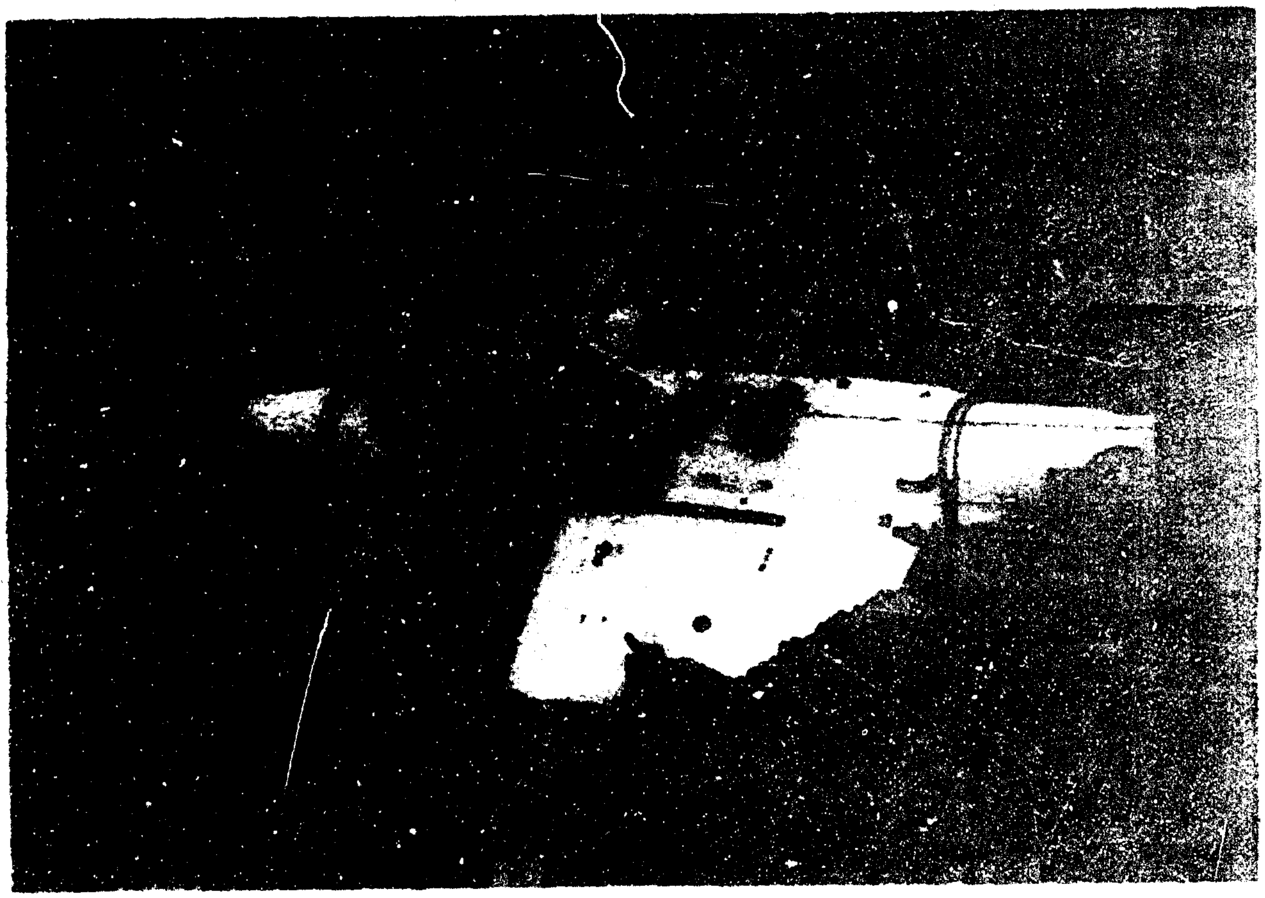

Figure 13. Target Aircraft in -45° Position, Top-Left View

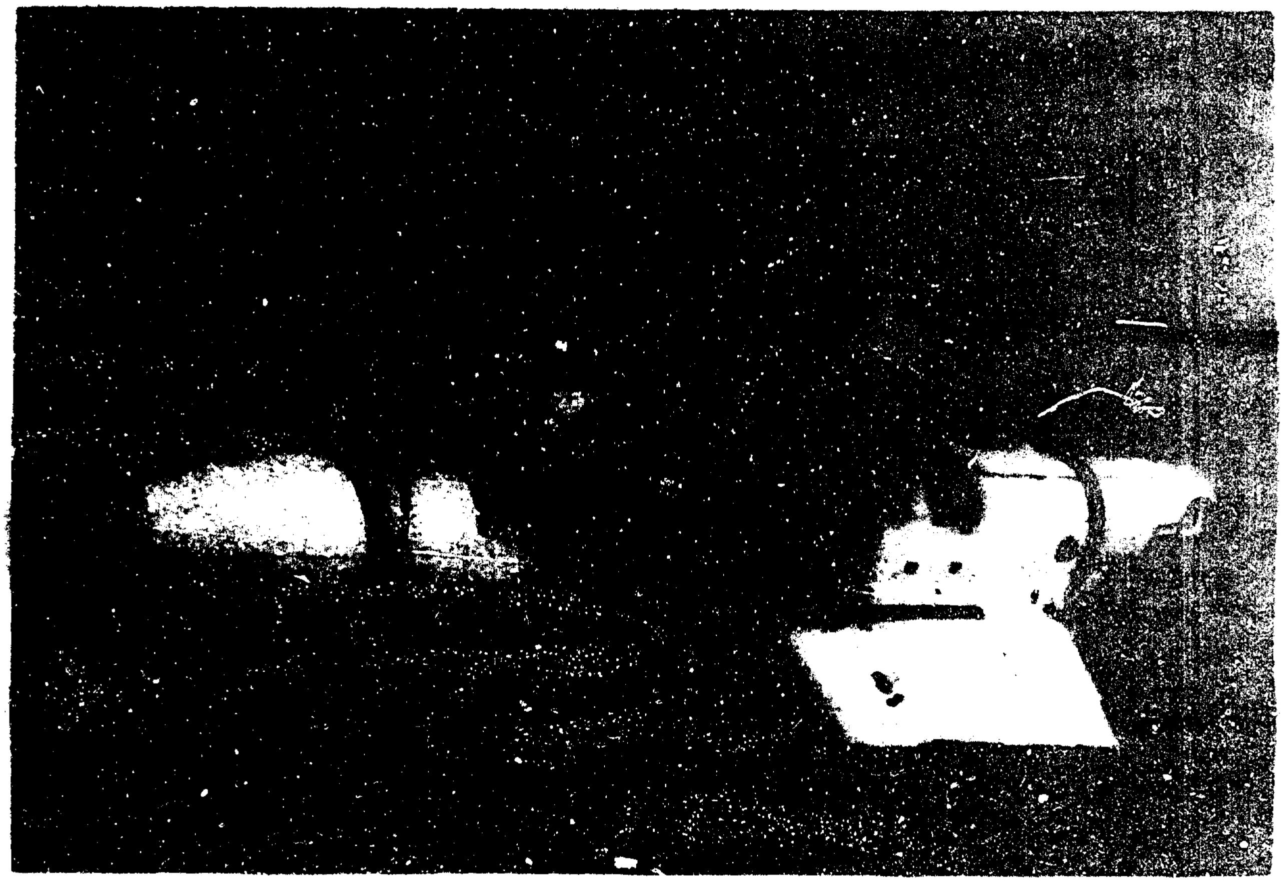

Figure 14. Target Aircraft in -45° Position, Top-Front View

Figure 15. Target Aircraft in -45° Position, Bottom View

TABLE III. FINAL FIRING PLAN

[illegible]	SHOT NO.	AZIMUTH	ELEVATION	FUSELAGE STATION	WATER LINE	AMMO CALIBER AND TYPE	REQUIRED IMPACT VELOCITY (FPS)	DATE FIRED
90°	1	54.22°	0°	143.72	67.62	.50 AP	3120	17 Dec 68
90°	2	14.96°	4.63°	14.38	101.11	.50 AP	3450	29 Oct 68
90°	3	45.33°	3.4°	124.16	70.94	.50 AP	3420	17 Dec 68
90°	6	19.82°	9.52°	69.97	102.92	.50 AP	3480	29 Oct 68
90°	7	29.52°	9.68°	87.42	84.89	.50 AP	3520	30 Oct 68
90°	9	29.78°	19.70°	121.91	101.94	.50 AP	3490	30 Oct 68
90°	14	90.0°	10.54°	204.25	57.24	.50 AP	3170	26 Nov 68
90°	15	90.0°	20.71°	204.25	60.95	.50 AP	3490	27 Nov 68
90°	19	90.0°	16.11°	267.50	57.86	.50 AP	2850	27 Nov 68
90°	26	153.98°	7.17°	314.19	58.32	.50 AP	2470	20 Jan 69
90°	27	145.02°	0°	390.00	68.34	.50 AP	2050	16 Dec 68
90°	28	137.98°	21.11°	346.63	82.71	.50 AP	2220	27 Nov 68
90°	32	131.99°	20.38°	268.32	61.81	20mm FSP	3500	26 Nov 68
90°	33	145.28°	8.21°	388.41	70.21	20mm FSP	3500	25 Nov 68
90°	34	19.82°	9.52°	69.96	102.92	20mm FSP	3500	13 Nov 68
90°	36	90.0°	20.71°	204.25	60.96	20mm FSP	3500	27 Nov 68
90°	37	54.22°	0°	143.72	67.62	.30 AP	3240	17 Dec 68
90°	38	54.22°	0°	143.72	67.62	.30 AP	3240	18 Dec 68
90°	39	54.22°	0°	143.72	67.62	.30 AP	3240	18 Dec 68
80°	8	[illegible].88°	18.53°	123.93	121.34	.50 AP	3420	20 Dec 68
80°	11	[illegible].60°	17.48°	147.45	106.59	.50 AP	3320	18 Dec 68
80°	12	57.45°	21.68°	168.60	101.57	.50 AP	3230	20 Dec 68
80°	13	64.98°	15.08°	163.43	70.38	.50 AP	3170	19 Dec 68
80°	16	43.63°	8.73°	168.02	64.46	.50 AP	3440	18 Dec 68
80°	22	17.72°	22.70°	207.32	122.26	.50 AP	3280	19 Dec 68
80°	35	20.88°	18.53°	123.93	121.34	20mm FSP	3500	20 Dec 68
80°	43	57.45°	21.68°	168.60	101.57	.30 AP	3010	20 Dec 68
90°	44	57.45°	21.68°	168.60	101.57	.30 AP	3010	20 Dec 68
80°	45	57.45°	21.68°	168.60	101.57	.30 AP	3010	20 Dec 68
55°	12	60.02°	0.3°	168.60	101.57	.50 AP	3230	4 Feb 69 (Repeat-See 80°)
55° *	17	60.67°	6.50°	231.91	---	.50 AP	3230	5 Feb 69
55° **	18	77.23°	3.4°	253.18	---	.50 AP	3040	5 Feb 69
55°	20	80.23°	9.28°	193.78	89.01	.50 AP	2900	4 Feb 69
55°	30	64.37°	15.30°	183.02	104.46	20mm FSP	3500	7 Dec 69
55°	31	111.13°	5.83°	230.29	82.04	20mm FSP	3500	7 Feb 69

TABLE III. (CONCLUDED)

POSITION	SHOT NO.	AZIMUTH	ELEVATION	FUSELAGE STATION	WATER LINE	AMMO CALIBER AND TYPE	REQUIRED IMPACT VELOCITY (FPS)	DATE FIRED
55°	43	60.02°	0.3°	168.60	101.57	.30 AP	3010	5 Feb 69 (Repeat-see 80°)
55°	44	60.02°	0.3°	168.60	101.57	.30 AP	3010	5 Feb 69 (Repeat-see 80°)
55°	45	60.02°	0.3°	168.60	101.57	.30 AP	3010	5 Feb 69 (Repeat-see 80°)
55°*	46	60.67°	6.50°	231.91	---	.30 AP	2720	7 Feb 69
55°*	47	60.67°	6.50°	231.91	---	.30 AP	2720	7 Feb 69
55°*	48	60.67°	6.50°	231.91	---	.30 AP	2720	7 Feb 69
45°	10	37.87°	1.35°	147.22	121.84	.50 AP	3410	21 Jan 69
45°	24	45.93°	15.00°	173.14	101.81	.50 AP	3230	22 Jan 69
45°	25	28.92°	11.47°	157.20	121.88	.50 AP	3260	4 Feb 69
-55°	21	-80.23°	9.28°	193.78	89.01	.50 AP	2900	12 Feb 69
-55°	23	-24.92°	13.53°	207.32	122.26	.50 AP	3280	12 Feb 69
-55°	29	-44.73°	0.87°	145.00	85.64	20mm PSP	3500	12 Feb 69
-90°	4	50.10°	2.35°	134.69	69.10	.50 AP	3280	24 Feb 69
-90°	5	29.75°	4.58°	77.33	79.44	.50 AP	3500	24 Feb 69
-90°	40	50.10°	2.35°	134.69	69.10	.30 AP	3080	24 Feb 69
-90°	41	50.10°	2.35°	134.69	69.10	.30 AP	3080	24 Feb 69
-90°	42	50.10°	2.35°	134.69	69.10	.30 AP	3080	24 Feb 69

* Wing Station 43.07

** Wing Station 39.38

SECTION V

SUMMARY

This report presents the methodology that was used to transform an original firing plan into a usable ballistic field test program. This transformation determined relationships of the target aircraft's coordinate system with respect to a fixed ground coordinate system. Included in field note form are the transcripts of the firing records (See Appendix III). Appendix IV explains the loading techniques used and presents load versus impact velocity tables obtained during these tests.

After installation of the armor panels, several fractures were observed on exterior panels. Only panels that had been shaped to fit the aircraft skin contour suffered these fractures. This phenomenon was not investigated.

This report made no attempt to analyze the firing data generated during the ballistic tests. A follow-on program will be conducted at Air Force Flight Dynamics Laboratory to determine these results.

APPENDIX I

TRANSFORMATION OF THE FIRING PLAN

In order to transform the firing plan in Table I into that in Table II, the MAGIC combinatorial geometry computer program was used. This program is normally used in vulnerability assessments of vehicular targets.

The MAGIC program produces a computerized geometric model of targets by combination of basic solid figures. Eight basic figures are used: sphere, rectangular parallelepiped, ellipsoid, right circular cylinder, truncated right circular cone, right elliptical cylinder, right angle wedge, and arbitrary convex polyhedron (4, 5, or 6 sides, 3 or 4 vertices). In applying the combinatorial approach, each one of these figures must be considered as a set of geometrical points in space. The figures are then combined into regions using three logical operators: +, -, and OR. These operators have the meaning of intersection, difference, and union, respectively. By position and super-position of the eight basic solids and their combination using the three operators, any solid in space can be approximated to any desired degree of accuracy.

Figure I-1 illustrates the use of these operators. In Figure I-1(A), two bodies e.g., sphere and a rectangular parallelepiped are shown as described in space. Figures I-1(B) through I-1(C), and I-1(D) illustrate possible combinations of these bodies into regions which can be described as follows:

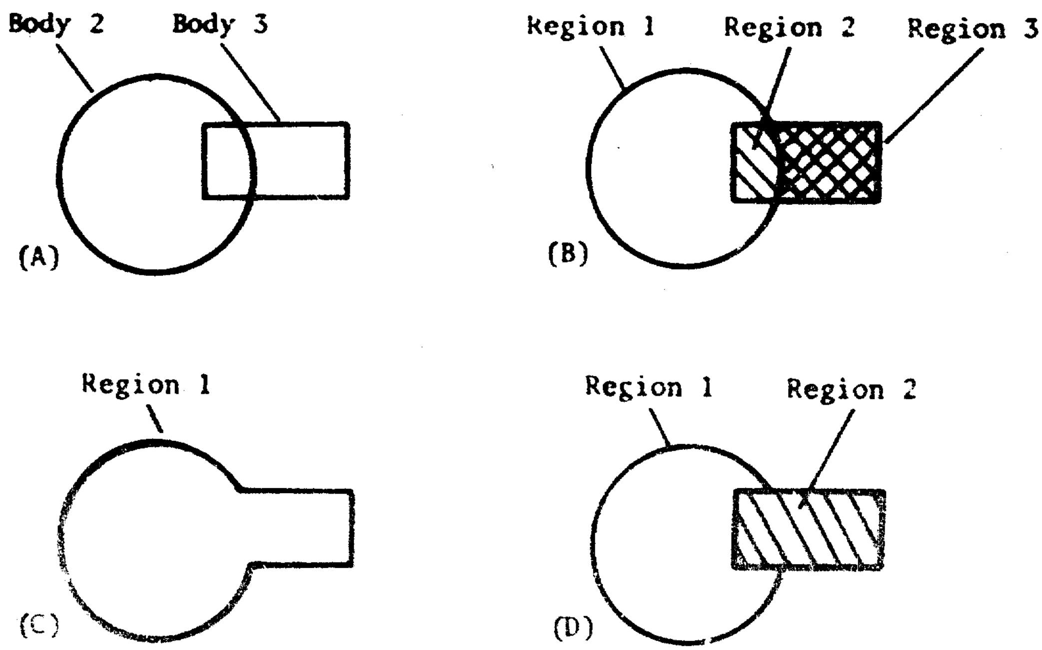

Figure I-1. The Use of Logical Operators in MAGIC

a. Figure I-1(B):
   Region 1 = +2-3
   Region 2 = +2+3
   Region 3 = +3-2

b. Figure I-1(C):
   Region 1 = OR2OR3

c. Figure I-1(D):
   Region 1 = +2-3
   Region 2 = OR3 + 2OR3

In its normal operation, MAGIC generates random parallel rays from specified attack aspect angles. Each ray is traced through the target, and for each component (region) encountered the following information is generated: entrance obliquity angle, line-of-sight distance, and normal distance (distance through the component on a line normal to the entering surface). These data, in conjunction with penetration mechanics and component damage data, are used to make vulnerability estimates of vehicular targets to single fragments and projectile impacts.

The MAGIC program includes a special subroutine (subroutine TESTG) used to generate specific single rays. This subroutine is normally used to debug errors in body or region descriptions. By specifying a starting and ending point in space, this subroutine will generate a ray between the two specified points. At each intersection with a region, it will print out the coordinates (x, y, z) of the contact point, the distance traveled from the previous contact point, and the total distance from the starting point. In addition, it will calculate the direction cosines for the ray.

Subroutine TESTG in the MAGIC program was used in transforming the firing plan in Table I to that in Table II.

From Table I the point P in each shot line is the target point (pilot's head, pilot's torso, etc). The direction numbers describe a point:

$$P_1 \ (x + \Delta x, \ y + \Delta y, \ z + \Delta z)$$

where x, y, z are the coordinates of P, and Δx, Δy, Δz are the direction numbers. From the magnitude of the direction numbers, it can be seen that the point P_1 lies very close to P, and both lie inside the aircraft. In order to use MAGIC for calculations of the entrance points, it was necessary to calculate starting points outside the target. The equation of the line in parametric form was used:

$$x - x_1 = t\,(x_2 - x_1)$$
$$y - y_1 = t\,(y_2 - y_1) \qquad \text{(I-1)}$$
$$z - z_1 = t\,(z_2 - z_1)$$

or

$$\frac{x - x_1}{\Delta x} = \frac{y - y_1}{\Delta y} = \frac{z - z_1}{\Delta z} \qquad \text{(I-2)}$$

In this case the coordinates of the point P were used as x_1, y_1, z_1, and x, y, z are the coordinates of the point sought.

Using Equation (I-2), an aribtrary starting point outside of the aircraft was calculated for each shot line. This point, along with point P, was used as input to the Magic TESTG subroutine.

In order to facilitate usage of the output, a coordinate system was selected to coincide with the aircraft fuselage station - water line - wing station coordinate system. The system was a right-hand cartesian one, with origin at fuselage station 0, water 100, along the fuselage centerline (see Figure 5).

In aiming the shots, it is convenient to use azimuth and elevation angles instead of direction cosines (see Figure 4).

If an arbitrary vector with length R and components x, y, z is considered such that the angles between the vector and the X, Y, Z axis α, β, and γ, its respective direction cosines λ, μ, and ν are:

$$\lambda = \cos\alpha$$
$$\mu = \cos\beta \qquad \text{(I-3)}$$
$$\nu = \cos\gamma$$

From basic trigonometry, it is true that:

$$\lambda = \frac{x}{R}$$
$$\mu = \frac{y}{R} \qquad \text{(I-4)}$$
$$\nu = \frac{z}{R}$$

From Figure 4 and the definition of a tangent, the azimuth A and elevation E are defined by:

$$\text{Tan } A = y/x$$
$$\text{Tan } E = \frac{z}{\sqrt{x^2 + y^2}} \qquad (I-4)$$

If an arbitrary vector of length (R=1) is selected from Equation (I-4), the direction cosines are identical to the x, y, z components. Therefore, λ, μ, ν can be used in place of x, y, and z in Equation (I-5).

This method was applied in calculating the azimuth and elevation angles listed in Table II. The fuselage station, water line, and wing station numbers were obtained directly from the MAGIC TESTG output. Note that, knowing whether the shot comes from the left or right side, only two of these three coordinates are needed to define an aiming point on the aircraft skin.

APPENDIX II

TRANSFORMATION OF COORDINATES

In order to facilitate the actual aiming of the gun, a fixed coordinate system on the ground was selected. A transit was used in measuring azimuth angles and an angle gauge for measuring elevation angles (the angle gauge works with gravity). However, Section III depicted positions of the aircraft at several angles with the ground (see Figures 6 through 15). Therefore, for each position of the aircraft, the aiming angles of the shots to be fired from that position were transformed from the aircraft coordinate system to the ground coordinate system.

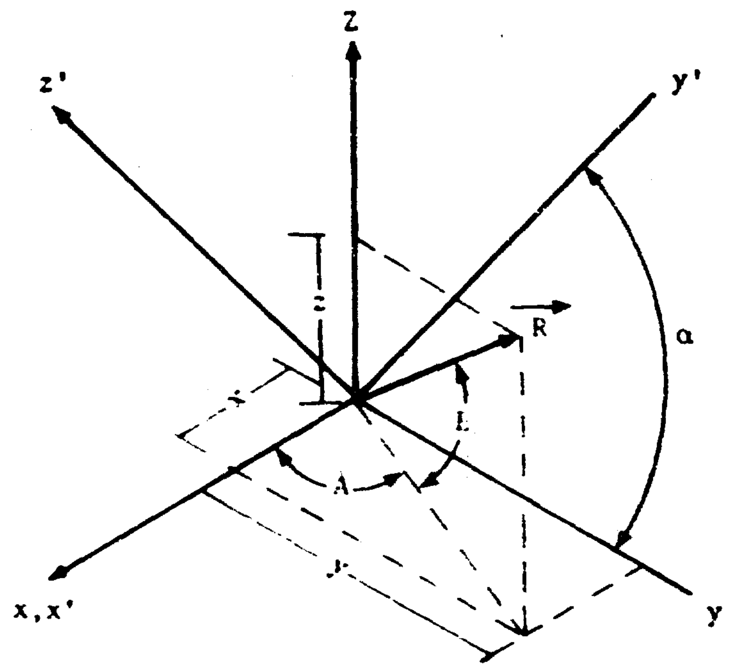

Figure II-1. Transformation of Coordinates

With reference to Figure II-1, let the unprimed coordinate system be fixed to the aircraft with the x-axis coinciding with its centerline. The prime system then will be fixed to the ground. Let α be the angle of the ground with respect to the aircraft (the negative of the position angle listed in Table III). This choice of coordinates reduces the problem to one of a rotation about the x-axis. For an arbitrary vector with components x, y, z, its transformed x', y', z' components (for any arbitrary rotation) can be expressed as:

$$x' = x\Omega_{11} + y\Omega_{12} + z\Omega_{13}$$
$$y' = x\Omega_{21} + y\Omega_{22} + z\Omega_{23} \qquad \text{(II-1)}$$

where Ω_{ik} is the direction cosine of the i^{th} prime axis with respect to the k^{th}, the unprimed axis.

From the definition of Ω_{ik} and Figure II-1, it can be seen that:

$$\Omega_{11} = 1$$
$$\Omega_{12} = 0$$
$$\Omega_{13} = 0$$
$$\Omega_{21} = 0 \qquad \text{(II-2)}$$
$$\Omega_{22} = \cos \alpha$$
$$\Omega_{23} = \sin \alpha$$
$$\Omega_{31} = 0$$
$$\Omega_{32} = \sin \alpha$$
$$\Omega_{32} = \cos \alpha$$

Substituting Equation (II-2) into Equation (II-1):

$$y' = x$$
$$y' = y \cos + z \sin \alpha \qquad \text{(II-3)}$$
$$z' = -y \sin = z \cos \alpha$$

From Equation (I-4), Appendix I, a vector, starting at the origin and having unit length, has its x, y, z components equivalent to its direction cosines. Therefore, with the direction cosines calculated by the computer (Appendix I) and the angle between the aircraft wing (y-axis) and the ground, Equation (II-3) can be used to calculate direction cosines for any shot line with respect to the ground coordinates. These generated values can then be substituted into Equation (I-5), (Appendix I), to calculate azimuth and elevation angles of the shot lines relative to the ground. This method was employed in generating the angles given in Table III.

APPENDIX III

FIRING RECORDS

This appendix contains the transcripts of the firing records prepared during the inspection after each shot. No attempt was made to reduce or analyze these data. All firings were conducted on Test Area C-74L of the Eglin AFB reservation.

FIRING RECORDS

Date: 29 Oct 68	Round No. 1
Shot No. 2	Projectile Caliber: .50
Range: C-74L	Gunner: Clyde Wallace
Recorder: George W. Ducker	
Required Vel: 3450 fps	Actual Vel: 3524 fps
Powder Type: IMR 4350	Powder Wt: 365 grains

Remarks: Firing occurred at 1040. Projectile impacted within an inch of the target point, left of the vertical line, just aft of the radome bulkhead. It penetrated the left radar compartment access door, emerging at the second rib. From this point the projectile either broke up into a number of pieces, generated a number of spall particles, or both. Some particles damaged the inside skin of the radar compartment door aft of the point of penetration. Other particles plowed through the upper right corner of a component mounted on rack No. 51449363-589, severed a wire bundle, and nearly severed a tube which passes over the top of the component. Two holes and a dent were made in the aft radar compartment bulkhead (the forward bulkhead of the forward fuel cell) at widely separated points, indicating that at least two particles penetrated the forward fuel cell. During damage assessment, a strong fuel odor was noted. The nose tank fuel filler cap was loosened. Fuel poured out. The cap was removed, and the fuel was allowed to drain.

Date: 29 Oct 68	Round No. 2
Shot No. 6	Projectile Caliber: .50
Range: C-74L	Gunner: Clyde Wallace
Recorder: George W. Ducker	
Required Vel: 3480 fps	Actual Vel: 3494 fps
Powder Type: IMR 4350	Powder Wt: 365 grains

Remarks: Firing occurred at 1325. At projectile impact, a fuel fire erupted in the fuel cell. The fire spread to the ground through the nose tank fuel filler opening. It was smothered with portable CO_2 extinguishers. The projectile impacted within an inch of the target point, left of the vertical centerline. It penetrated the left radar compartment access door, about two inches forward of the aft edge;

penetrated the forward bulkhead of the forward fuel cell near the mold line; and penetrated the aft fuel cell bulkhead breaking up a large section of a stiffener flange. A large number of particles gouged dents in the next bulkhead. The major particle penetrated the compartment, almost completely severed a wire bundle, and made a small dent in the forward surface of the forward armor panel. A large piece of the round was recovered in the compartment forward of the front armor panel. It was approximately a third of the projectile mass--the rear part. It is doubtful that the projectile would have penetrated the aft fuel cell bulkhead had the fuel cell been full.

Date: 1 Nov 68	Round No. 1
Shot No. 9	Projectile Caliber: .50
Range: C-74L	Gunner: Clyde Wallace
Recorder: George W. Ducker	
Required Vel: 3490 fps	Actual Vel: 3515 fps
Powder Type: IMR 4350	Powder Wt: 365 grains

Remarks: The projectile impacted less than an inch from the target point. It damaged the base of the left forward pitot tube, penetrated the skin into the radio and electrical compartments, penetrated a bulkhead and shelf installation, cut the pitot installation cable, and damaged an instrument mount, breaking up in the passage. Four large particles penetrated a partial bulkhead, damaging Nadar Controls No. 1 and 2, and impacted against the forward armor panel. Four surface scars were left on the armor panel.

Date: 1 Nov 68	Round No. 2
Shot No. 7	Projectile Caliber: .50
Range: C-74L	Gunner: Clyde Wallace
Recorder: George W. Ducker	
Required Vel: 3520 fps	Actual Vel: 3534 fps
Powder Type: IMR 4350	Powder Wt: 365 grains

Remarks: The projectile penetrated the skin into the forward fuel cell, apparently breaking up in the process. At least two particles penetrated the aft fuel cell bulkhead in two places, damaged fuel line 5104587 in two places and compartment vent 5104587 8413, penetrated the next bulkhead in one place, and tore a large hole in the next bulkhead adjacent to Nadar Controls No. 1 and 2, further damaging them. Two almost imperceptible dents were made in the front armor panel. Further inspection revealed that one particle was deflected by fuel line 5104587, resulting in a deep crease in the line. A small piece of the tip of the projectile was recovered. It was photographed.

Date: 25 Nov 68
Shot No. 33
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: 20mm FSP
Gunner: Clyde Wallace

Actual Vel: 3565 fps
Powder Wt: 425 grains

Remarks: The FSP impacted directly on the aiming point and traveled through the nacelle tail-cone assembly. It was recovered from the cavity behind the access door in front of the jack pad location sign. Secondary fragments created by the FSP penetrated into the engine outlet (afterburner), and some were deflected outward from within the engine through the aircraft skin forward of the impact point. The FSP weight after impact equaled 694.2 grains.

Date: 26 Nov 68
Shot No. 32
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: 20mm FSP
Gunner: Sgt Farris

Actual Vel: 333 fps
Powder Wt: 425 grains

Remarks: The FSP impacted the aircraft exactly on the aiming point. It perforated an insulated hose just behind the outside skin. The path for the FSP could not be traced any further.

Date: 26 Nov 68
Shots No. 14a and 14b
Range: C-74L
Recorder: Mr. M. R. Gromosiak
Required Vel: 3170 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50 AP
Gunner: Sgt Farris

Actual Vel: 3155 and 3175 fps
Powder Wt: 305 grains

Shot 14a

Remarks: The projectile impacted the aircraft five inches above the aiming point. It penetrated into the engine inlet dome. It continued through the inlet, penetrated the other side, and entered the pilot's cockpit through the forward end of the outboard throttle slot in the control pedestal in the left-hand console, creating secondary fragments that impacted along with the projectile into the inside surface of the cockpit just below the forward left corner of the canopy. No secondary fragments impacted the wallboard blocks located in the cockpit. The projectile was recovered intact. Since the aiming point for shot No. 14 was missed by such a wide margin, it was decided to repeat the shot.

Shot 14b

Remarks: The projectile impacted directly on the aiming point and penetrated into the inlet. After perforating the engine inlet dome, it dispersed downward to the left of the path followed by projectile 14a. The path of the projectile could not be traced after impacting the other side of the inlet.

Date: 27 Nov 68
Shot No. 36
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 3500 fps
Powder Type: IMR 4350
Round No. 1
Projectile Caliber: 20mm FSP
Gunner: Sgt Farris
Actual Vel: 3497 fps
Powder Wt: 430 grains

Remarks: The FSP impacted the aircraft two inches above the aiming point. It entered the cockpit through the left console just aft of the control pedestal and just outboard of the flap control. It passed through the cockpit undisturbed, impacting the ground approximately 25 feet away from the aircraft. Examination of the line of fire for the FSP indicated that an error in orienting the line of fire may have occurred.

Date: 27 Nov 68
Shot No. 15
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 3490 fps
Powder Type: IMR 4350
Round No. 2
Projectile Caliber: .50 AP
Gunner: Sgt Farris
Actual Vel: 3361 fps
Powder Wt: 350 grains

Remarks: The projectile impacted the aircraft 1/4 inch below the aiming point and entered the engine inlet above the path followed by shot No. 14a. After perforating the top of the engine inlet dome, it traveled to the other side of the inlet and penetrated into the cockpit between the flap control and the control pedestal and was recovered. Secondary fragments traveled undisturbed away from the exit area, impacting the inside surface of the pilot's cockpit below the left rim of the canopy.

Date: 27 Nov 68
Shot No. 19
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 2850 fps
Powder Type: IMR 4359
Round No. 3
Projectile Caliber: .50 AP
Gunner: Sgt Farris
Actual Vel: 2994 fps
Powder Wt: 290 grains

Remarks: The projectile impacted the aircraft 1/2 inch from the aiming point. The path of the projectile could not be traced.

Date: 27 Nov 68
Shot No. 28
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 2220 fps
Powder Type: IMR 4350

Round No. 4
Projectile Caliber: .50 AP
Gunner: Sgt Farris
Actual Vel: 2381 fps
Powder Wt: 200 grains

Remarks: The projectile impacted the aircraft right on the aiming point. The path of the projectile could not be traced.

Date: 16 Dec 68
Shots No. 27a and 27b
Range: C-74L
Recorder: G. Ducker
Required Vel: 2050 fps
Powder Type: IME 4350

Round No. 1
Projectile Caliber: .50 AP
Gunner: Sgt Farris
Actual Vel: 2232 and 2241 fps
Powder Wt: 195 and 185 grains

27a
Remarks: The projectile was fired from the rear of the aircraft at the lower surface of the left engine nacelle. It impacted the engine access door about four inches aft of the impact point. This shot will be repeated.

27b
Remarks: The projectile impacted about an inch from the impact point. Damage assessment was not possible because the access doors could not be opened. The latches were inoperative, probably due to corrosion or structural displacement, and opening tools were not available. Access to the damage area through the engine outlet was not possible due to intervening structure.

Date: 17 Dec 68
Shot No. 3
Range: C-74L
Recorder: G. Ducker
Required Vel: 3420 fps
Powder Type: 4350

Round No. 1
Projectile Caliber: .50 AP
Gunner: Sgt Farris
Actual Vel: 3401 fps
Powder Wt: 365 grains

Remarks: The projectile impacted within an inch of the impact point, perforated the skin and a frame, perforated the bulkhead forward of the nose gear wheel well, and entered the wheel well near the top. It was not possible to determine the course of the bullet past that point. A number of secondary particles were generated by the passage of the bullet through the compartment forward of the wheel well. One of these shattered the face of a pressure gauge on the forward face of the forward bulkhead of the nose gear wheel well.

Date: 17 Dec 68 | **Round No.** 2
Shot No. 1
Range: C-74L
Recorder: G. W. Ducker
Required Vel: 3120 fps
Powder Type: 4350

Projectile Caliber: .50 AP
Gunner: Sgt Farris
Actual Vel: 3086 fps
Powder Wt: 300 grains

Remarks: The projectile impacted on the landing gear light. It perforated the light, perforated the nose gear wheel well bulkhead, penetrated the nose gear strut, and exited the strut about three inches aft of its entrance point. The projectile was not recovered. There were a number of damage points on the nose gear wheel and other components which appeared to have been caused by secondary particles. The damage to the strut was such that it was impossible to extend the nose gear. In operation, the pilot would have had to make a gear-up or emergency landing or eject.

Date: 17 Dec 68
Shot No. 37
Range: C-74L
Recorder: G. W. Ducker
Required Vel: 3240 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: .30 AP
Gunner: Sgt Farris
Actual Vel: 3130 fps
Powder Wt: 112 grains

Remarks: The projectile passed through the hole in landing light made by shot No. 1. In passage, it further damaged the light filaments, generating some small fragments which perforated the No. 1 marker left on the reflector. The projectile passed through the hole in the bulkhead made by shot No. 1. It generated secondary particles which made additional marks on the nose wheel assembly. No other significant damage was noted. A piece of the projectile from shot No. 1 was found after this shot.

Date: 18 Dec 68
Shot No. 38
Range: C-74L
Recorder: A. A. Santiago and G. Ducker
Required Vel: 3240 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .30 AP
Gunner: Sgt Farris
Actual Vel: 3096 fps
Powder Wt: 117 grains

Remarks: The projectile passed through the hole made by shot No. 1. Some additional damage to the nose gear mechanism was observed. Full assessment was not possible since the nose gear was stuck in the UP position.

Date: 18 Dec 68	**Round No. 2**
Shot No. 39	**Projectile Caliber: .30 AP**
Range: C-74L	**Gunner: Sgt Farris**
Recorder: A. A. Santiago and G. Ducker	
Required Vel: 3240 fps	**Actual Vel: 3466 fps**
Powder Type: IMR 4350	**Powder Wt: 130 grains**

Remarks: The projectile passed through the hole made by shot No. 1. When the nose gear was pulled out, extensive additional damage was found on the strut and the components on the upper nose gear bulkhead.

Date: 18 Dec 68	Round No. 3
Shot No. 16	Projectile Caliber: .50 AP
Range: C-74L	Gunner: Sgt Farris
Recorder: A. A. Santiago and G. Ducker	
Required Vel: 3440 fps	Actual Vel: 3539 fps
Powder Type: IMR 4350	Powder Wt: 365 grains

Remarks: The projectile impacted on the aim point. It perforated the engine nacelle and was deflected upward through a corner of the aft panel of the left console. It damaged the seat back support structure and broke a lug from the seat mounting bracket. The seat bottom cylinder was also damaged. The bullet would have missed the pilot since the line of flight was aft of the seat back.

Date: 18 Dec 68	Round No. 4
Shot No. 11	Projectile Caliber: .50 AP
Range: C-74L	Gunner: Sgt Farris
Recorder: G. W. Ducker	
Required Vel: 3320 fps	Actual Vel: 3328 fps (est)
Powder Type: IMR 4350	Powder Wt: 360 grains

Remarks: The velocity timer did not function properly, possibly because the force of the shot blew the lead wires against the surface of the aircraft and shorted them out. The projectile impacted a fraction of an inch above the impact point, plowed under the forward upper left armor panel, penetrated the cockpit, impacted the celotex bundle in the pilot's seat near the lower left edge at layer No. 5, and penetrated to layer 18. The projectile had fragmented and left little pieces at each layer. The piece in layer 18 was the largest. The forward upper left corner of the armor panel was already cracked. The bullet finished breaking that corner loose from the panel. The attaching bolt and the rubber liner bonded to the panel held that piece on the aircraft. The bullet fragment weighed 54.8 grains. Penetration of seven inches of Nuwood means a velocity of 1915 fps, a kinetic energy of 445 foot-pounds. Had the fragment impacted the pilot's left thigh, it would not have been fatal. Had it hit the groin or lower abdomen, it would almost certainly have been fatal.

Date: 19 Dec 68
Shot No. 22
Range: C-74L
Recorder: G. W. Ducker
Required Vel: 3280 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50 AP
Gunner: Sgt Farris

Actual Vel: 3306 fps
Powder Wt: 355 grains

Remarks: The projectile impacted on the third armor panel aft, left side, at a high angle of obliquity. It ricocheted, making only a superficial mark on the armor panel. The projectile missed the impact point by about seven inches, but since the impact point was also on the armor panel, it was not considered necessary to repeat the shot.

Date: 19 Dec 68
Shot No. 13
Range: C-74L
Recorder: G. W. Ducker
Required Vel: 3170 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50 AP
Gunner: Sgt Farris

Actual Vel: 3210 fps
Powder Wt: 340 grains

Remarks: The projectile impacted almost on the aim point. It perforated the outboard wall of the engine inlet. A number of secondary particles were generated. The major particles perforated the inboard walls of the inlet and, apparently, perforated the cockpit floor below the left rear cockpit console, damaging the console panel.

Date: 19 Dec 68
Shot No. 8A
Range: C-74L
Recorder: G. W. Ducker
Required Vel: 3420 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: .50 AP
Gunner: Sgt Farris

Actual Vel: 3472 fps
Powder Wt: 370 grains

Remarks: The projectile impacted approximately one foot aft of the aim point. It plowed a furrow through the skin, hit the pilot's canopy, and ricocheted away from the aircraft. This shot will be repeated.

Date: 20 Dec 68
Shot No. 8
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3420 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50
Gunner: Sgt Farris

Actual Vel: -- (No counter reading)
Powder Wt: 370 grains

Remarks: (This shot was repeated because of bad hit.) No counter reading was made. Good hit. Penetrated one inside panel and hit armor plate behind the cockpit. (Broke a wire bundle.) Two big holes were observed in the inside panel and two big marks on the plate.

Date: 20 Dec 68
Shot No. 35
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: 20mm
Gunner: Sgt Farris

Actual Vel: 3515 fps
Powder Wt: 425 grains

Remarks: Good hit. Same entrance as No. 8 but deflected and came out in front of windshield (still on the metal part; bounced off the edge of the armor plate). Evidence of big fragments outside projectile path probably indicates breakup.

Date: 20 Dec 68
Shot No. 12
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3280 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: .50
Gunner: Sgt Farris

Actual Vel: 3339 fps
Powder Wt: 345 grains

Remarks: Good hit. Could not find the hole in the cockpit area, although it missed all the armor. Pieces of metal laying on the celotex.

Date: 20 Dec 68
Shot No. 43
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3010 fps
Powder Type: IMR 4350

Round No. 4
Projectile Caliber: .30
Gunner: Sgt Farris

Actual Vel: 2817 fps
Powder Wt: 100 grains

Remarks: Good hit. Again only entrance hole was observed.

Date: 20 Dec 68
Shot No. 44
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3010 fps
Powder Type: IMR 4350

Round No. 5
Projectile Caliber: .30
Gunner: Sgt Farris

Actual Vel: 3196 fps
Powder Wt: 110 grains

Remarks: Same as above. More pieces found on celotex but no penetration on the bundles.

Date: 20 Dec 68
Shot No. 45
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3010 fps
Powder Type: IMR 4350

Round No. 6
Projectile Caliber: .30
Gunner: Sgt Farris

Actual Vel: 3301 fps
Powder Wt: 105 grains

Remarks: After finishing the sequence, the seat was removed. Extensive damage was observed around the landing gear control area. Projectiles have been deflecting up and hitting the outside armor from the inside. Shot No. 45, however, flew straight, hitting the pilot's chest; no penetration on the celotex due to high impact obliquity angle.

Date: 20 Jan 69
Shot No. 26
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 2470 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50 AP
Gunner: Sgt Frayer

Actual Vel: No counter reading
Powder Wt: --

Remarks: The projectile impacted within 1/4 inch of the aiming point. After impacting into the aft engine shroud, the projectile's path could not be traced any further.

Date: 21 Jan 69
Shot No. 27
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 2050 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50 AP
Gunner: Sgt Frayer

Actual Vel: No counter reading
Powder Wt: --

Remarks: Shot No. 27 impacted within one inch of the aiming point. The path of the projectile could not be traced any further.

Date: 21 Jan 69
Shot No. 10
Range: C-74L
Recorder: M. R. Gromosiak
Required Vel: 3410 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50 AP
Gunner: Sgt Frayer

Actual Vel: 3165 fps
Powder Wt: 370 grains

Remarks: The projectile, after impacting the aiming point, passed under the first outside armor panel on the left side of the aircraft and perforated a structural rib located under the aircraft skin and in front of the instrument panel. It was impossible to determine if and where the projectile entered the cockpit due to the condition of the instrument panel and the damage in the cockpit inflicted by previous shots.

Date: 22 Jan 69
Shot No. 24
Range: C-74L
Recorder: M. R. Gronwsiak
Required Vel: 3230 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50 AP
Gunner: Sgt Frayer

Actual Vel: No counter reading
Powder Wt: 345 grains

Remarks: Shot No. 24 impacted within one inch of the aiming point. The path of the projectile could not be traced any further.

Date: 24 Feb 69
Shot No. 5
Range: C-74L
Recorder: G. Ducker
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50
Gunner: Sgt Frayer

Actual Vel: 3478 fps
Powder Wt: grains

Remarks: The bullet impacted about an inch above and aft of the impact point. It penetrated the skin on the lower surface of the aircraft to the right of the lower centerline, perforated the forward fuel cell, and perforated part No. 4606-88 on the aft fuel cell bulkhead. The size of the hole in this part indicated bullet breakup or the generation of large numbers of spall particles.

Date: 24 Feb 69
Shot No. 4
Range: C-74L
Recorder: G. Ducker
Required Vel: 3280 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50
Gunner: Sgt Frayer

Actual Vel: 3289 fps
Powder Wt: 340 grains

Remarks: The bullet impacted within 1/2 inch of the impact point. It perforated the skin about eight inches to the right of the lower centerline near the nose gear landing light. It perforated the forward nose gear wheel well bulkhead and passed through lightening hole in the nose gear truss assembly, damaging the edge of the hole. It appeared to have impacted a bolt on the strut assembly and shattered. The large ragged hole in the bulkhead indicates that bullet breakup began at that point, or a large number of spall particles were generated.

Date: 24 Feb 69
Shot No. 40
Range: C-74L
Recorder: G. Ducker
Required Vel: 3080 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: .30
Gunner: Sgt Frayer

Actual Vel: 2837 fps
Powder Wt: 102 grains

Remarks: The bullet impacted the impact mark made for shot No. 4. It perforated the skin and the nose gear wheel well bulkhead, increasing the size of the hole made by shot No. 4; made a hole in the truss near the path of shot No. 4 and caused additional damage to the top of the wheel well.

Date: 24 Feb 69
Shot No. 41
Range: C-74L
Recorder: G. Ducker
Required Vel: 3080 fps
Powder Type: IMR 4350

Round No. 4
Projectile Caliber: .30
Gunner: Sgt Frayer
Actual Vel: 3210 fps
Powder Wt: 105 grains

Remarks: The bullet impacted on the same point as shot No. 40, followed the same path through the wheel well forward bulkhead, and caused additional damage to the truss assembly. The bullet appeared to have damaged the brake valve assembly on the top surface of the wheel well. No pictures were taken.

Date: 24 Feb 69
Shot No. 42
Range: C-74L
Recorder: G. Ducker
Required Vel: 3080 fps
Powder Type: IMR 4350

Round No. 5
Projectile Caliber: .30
Gunner: Sgt Frayer
Actual Vel: 3267 fps
Powder Wt: 103 grains

Remarks: The bullet followed the path of shots No. 40 and 41. It caused additional damage to the wheel brake valve assembly, almost demolishing it.

Date: 4 Feb 69
Shot No. 25
Range: C-74L
Recorder: Lt Santiago
Required Velocity: 3260 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50
Gunner: Sgt Frayer
Actual Vel: 2773 fps
Powder Wt: 275 grains

Remarks: Projectile ricocheted from the outside panel; several marks were visible on the plastic behind the pilot's seat.

Date: 4 Feb 69
Shot No. 20
Range: C-74L
Recorder: Lt Santiago
Required Velocity: 2900 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50
Gunner: Sgt Frayer
Actual Vel: 2736 fps
Powder Wt: 260 grains

Remarks: Only the entrance point was found. No evidence of fragments on projectile in wallboard witness panels. Therefore, seat was not removed. From the attack aspect, it probably hit the side panel inside of the pilot's compartment.

Date: 4 Feb 69	Round No. 3
Shot No. 12	Projectile Caliber: .50
Range: C-74L	Gunner: Sgt Frayer
Recorder: Lt Santiago	
Required Vel: 3230 fps	Actual Vel: 2601 fps
Powder Type: IMR 4350	Powder Wt: 245 grains

Remarks: Projectile hit aiming point, penetrated between panels, and wounded the pilot around the left shoulder area (not certain whether it was a big fragment or the projectile itself). Witness panel on the side has a mark of a small fragment that penetrated it. Projectile came in front of throttle console area; perforated the side of seat and was recovered on the left foot rest.

Date: 5 Feb 69	Round No. 1
Shot No. 43	Projectile Caliber: .30
Range: C-74L	Gunner: Sgt Frayer
Recorder: Lt Santiago	
Required Vel: 3010 fps	Actual Vel: No reading
Powder Type: IMR 4350	Powder Wt: 100 grains

Remarks: Entrance point about one inch low of 12. No evidence of penetration either in witness wallboard or consoles.

Date: 5 Feb 69	Round No. 2
Shot No. 44	Projectile Caliber: .30
Range: C-74L	Gunner: Sgt Frayer
Recorder: Lt Santiago	
Required Vel: 3010 fps	Actual Vel: 2994 fps
Powder Type: IMR 4350	Powder Wt: 100 grains

Remarks: Hit between 12 and 43. There was evidence of small fragments flying around the pilot's left leg. Projectile apparently penetrated into the cockpit forward of the throttle console, but only evidence of small fragments was observed.

Date: 5 Feb 69	Round No. 3
Shot No. 45	Projectile Caliber: .30
Range: C-74L	Gunner: Sgt Frayer
Recorder: Lt Santiago	
Required Vel: 3010 fps	Actual Vel: 3016 fps
Powder Type: IMR 4350	Powder Wt: 101 grains

Remarks: Impacted right on 44. Penetrated around the same area as the others, penetrated witness wallboard, and wounded pilot's abdominal area. Evidence of small frag spall found on witness board.

Date: 5 Feb 69
Round No. 4
Shot No. 18
Projectile Caliber: .50
Range: C-74L
Gunner: Sgt Frayer
Recorder: Lt Santiago
Required Vel: 3040 fps
Actual Vel: 2924 fps
Powder Type: IMR 4350
Powder Wt: 285 grains

Remarks: Good hit. Projectile penetrated into the wing at the production line. Nothing observed on the other side or inside of the cockpit. Big hole right below entrance hole and holes on velocity screen indicate big fragments flying backward. One piece of the access door found about 75 feet from the aircraft (behind the gun).

Date: 5 Feb 69
Round No. 5
Shot No. 17
Projectile Caliber: .50
Range: C-74L
Gunner: Sgt Frayer
Recorder: Lt Santiago
Required Vel: 3230 fps
Actual Vel: 3226 fps
Powder Type: IMR 4350
Powder Wt: 325 grains

Remarks: Projectile penetrated wing around production point area. As far as can be seen, the hole seems to go in straight. No evidence of damage in radar operator's compartment.

Date: 7 Feb 69
Round No. 1
Shot No. 46
Projectile Caliber: .30
Range: C-74L
Gunner: Sgt Frayer
Recorder: Lt Santiago
Required Vel: 2720 fps
Actual Vel: 2635 fps
Powder Type: IMR 4350
Powder Wt: 85 grains

Remarks: Good hit. Observation same as for shot No. 17.

Date: 7 Feb 69
Round No. 2
Shot No. 47
Projectile Caliber: .30
Range: C-74L
Gunner: Sgt Frayer
Recorder: Lt Santiago
Required Vel: 2720 fps
Actual Vel: 2793 fps
Powder Type: IMR 4350
Powder Wt: 86 grains

Remarks: Good hit. Same as above.

Date: 7 Feb 69
Shot No. 48
Range: C-74L
Recorder: Lt Santiago
Required Vel: 2720 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: .30
Gunner: Sgt Frayer

Actual Vel: 2721 fps
Powder Wt: 86 grains

Remarks: Same as above.

Date: 7 Feb 69
Shot No. 31
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 4
Projectile Caliber: 20mm
Gunner: Sgt Frayer

Actual Vel: 3503 fps
Powder Wt: 430 grains

Remarks: Hit about one inch high; nothing observed but the entrance. Engine across doors will be opened later. They could not be opened due to aircraft position.

Date: 7 Feb 69
Shot No. 30
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3500
Powder Type: IMR 4350

Round No. 5
Projectile Caliber: 20mm
Gunner: Sgt Frayer

Actual Vel: 3521 fps
Powder Wt: 430 grains

Remarks: Hit about 1-1/2 inches low; complete penetration and heavy spall. Pilot wounded badly in left rib area. No armor plate was encountered in projectile path. Slug penetrated pilot bundle completely and stopped on the right side cockpit panel.

Date: 12 Feb 69
Shot No. 29
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3500 fps
Powder Type: IMR 4330

Round No. 1
Projectile Caliber: 20mm
Gunner: Sgt Frayer

Actual Vel: 3454 fps
Powder Wt: 430 grains

Remarks: Only entrance point was observed. After putting a cleaning rod through the hole as far as it would go, the projectile hit the right floor panel (ceramic).

Date: 12 Feb 69
Shot No. 23
Range: C-74L
Recorder: Lt Santiago
Required Vel: 3280 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50
Gunner: Sgt Frayer

Actual Vel: 3304 fps
Powder Wt: 355 grains

Remarks: Projectile hit about one inch short of point. Ricocheted off the third plate from the front (on right-hand side) and took off a bolt.

Date: 12 Feb 69
Shot No. 21
Range: C-74L
Recorder: Lt Santiago
Required Vel: 2900 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: .50
Gunner: Sgt Frayer

Actual Vel: 2932 fps
Powder Wt: 283 grains

Remarks: Impacted about two inches above point. A hole was found on the consoles on the right-hand side of the pilot's compartment, but no further damage was observed either in the cockpit area or on the seat.

ADDITIONAL SHOTS

Date: 30 Jul 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50
Gunner: TSgt Sauls
Actual Vel: No reading
Powder Wt: 370 grains

Remarks: Point of impact was 10 inches from top leading edge and 15 inches from the rear leading edge of the rear panel on the left side of the aircraft. Entrance hole was 1/2 inch in diameter. Impact splatter sheared off 1/4-inch-diameter armor retaining bolt head. Damage inside aircraft: MATTS transmitter had one hole 1/2 inch x 3/4 inch in facing; one relay had one hole 1/2 inch in diameter and three holes less than 1/2 inch in diameter; three wires were severed; wing main spar had one dent 3/4 inch x 3/4 inch; seat bracket for foot matting had one dent 1/8 inch and was cracked 5/8 inch on its face.

Date: 30 Jul 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: .50
Gunner: TSgt Sauls
Actual Vel: No reading
Powder Wt: 370 grains

Remarks: Point of impact was the top left-hand corner retaining bolt on the left rear panel of the aircraft. Entrance hole was 3/4-inch in diameter, removing the bolt head and 1-1/2 inches of the bolt. Damage sustained was one chip 1-1/2 inches x 1/2-inch of armor removed by force of the projectile impact, five inches from the top leading edge one crack 7 inches long and one chip 3/8-inch x 1-1/4 inches long. There was severe cracking around the impact hole. There was no internal damage sustained.

Date: 30 Jul 69	Round No. 4
Range: C-74L	Projectile Caliber: .50
Recorder: Lt Winger	Gunner: TSgt Sauls
Required Vel: 3500 fps	Actual Vel: No reading
Powder Type: IMR 4350	Powder Wt: 370 grains

Remarks: Point of impact was eight inches from the bottom leading edge of the armor plate on the joint between the 4 and 5 panel. Entrance hole was 2-1/2 inches x 3/4 inch in the armor and 3 inches x 2 inches in the aircraft skin. Damage sustained was 1-1/2 inches x 1/2-inch piece of support rib removed; console light panel - two cannon plugs destroyed, one hole 1/2-inch in diameter, six holes less than 1/2-inch in diameter; rear of case - one hole 1-1/2 inches x 3/4 inch; right foot rest - one hole 1-1/2 inches x 3.8 inch.

Date: 30 Jul 69	Round No. 5
Range: C-74L	Projectile Caliber: .50
Recorder: Lt Winger	Gunner: TSgt Sauls
Required Vel: 3500 fps	Actual Vel: No reading
Powder Type: IMR 4350	Powder Wt: 370 grains

Remarks: Point of impact was 14 inches from the top leading edge of the armor plate, 1/4 inch off center of the joint between the 3 and 4 panel. Entrance hole 3/4 inch x 1 inch. Entrance hole 4 inches x 2 inches in the skin went through a structural rib. Damage sustained: Fuel quantity bridge unit severed; high voltage box on the right-hand side had four holes less than 1/4-inch in diameter; wiring harness had eight wires severed on right-hand instrument panel. Circuit breaker panel had one hole 1/2 inch x 1 inch. Had a pilot been in the aircraft, he would have been 100 percent loss.

Date: 30 Jul 69	Round No. 6
Range: C-74L	Projectile Caliber: .50
Recorder: Lt Winger	Gunner: TSgt Sauls
Required Vel: 3500 fps	Actual Vel: 3484 fps
Powder Type: IMR 4350	Powder Wt: 370 grains

Remarks: Point of impact was six inches from rear leading edge and 1/2 inch below crack on the third panel. Entrance hole was 3/4 inch x 1 inch. Exit hole after armor was a 3-inch-diameter hole in skin of aircraft. Damage sustained was one cannon plug destroyed left side; cabin temperature alternate start switch panel - bent toggle switch; one hole 1/2 inch in diameter under automatic pilot panel in right-hand control panel. Pilot's middle thigh would have been 100 percent loss.

Date: 30 Jul 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 7
Projectile Caliber: .50
Gunner: TSgt Sauls
Actual Vel: 3490 fps
Powder Wt: 370 grains

Remarks: Point of impact was four inches to the rear of round No. 6 and one inch above the crack on the third panel. Entrance hole was 1-1/2 inches x 1 inch. Exit hole through the skin was 3-1/2 inches in diameter. Damage sustained was two cannon plugs severed; flap positioner destroyed; pilot's calf would have been 100 percent loss.

Date: 30 Jul 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 8
Projectile Caliber: .50
Gunner: TSgt Sauls
Actual Vel: 3502 fps
Powder Wt: 370 grains

Remarks: Point of impact was six inches behind leading edge and on the crack of the third panel, left side. Entrance hole was one inch in diameter. Exit hole through the skin was three inches in diameter. Damage sustained: Fragments missed control panel but were broken up by the seat ejection handle grip. Pilot would have been hit on his left knee and lower thigh.

Date: 30 Jul 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3200 fps
Powder Type: IMR 4350

Round No. 9
Projectile Caliber: .50
Gunner: TSgt Sauls
Actual Vel: 3294 fps
Powder Wt: --

Remarks: Point of impact was in the center of the fourth panel. There was no noticeable damage sustained.

Date: 1 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 1
Projectile Caliber: .50
Gunner: TSgt Sauls
Actual Vel: 3454 fps
Powder Wt: --

Remarks: Point of impact was eight inches behind leading edge and center of the second panel on the right side of the aircraft. Entrance hole was 1 inch x 3/4 inch. Fragment hit junction panel; 18 wires were severed. Single-phase and three-phase inverters were completely penetrated. Wing deicer: one hole 1/4 inch in diameter.

Date: 1 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 2
Projectile Caliber: 20mm FSP
Gunner: TSgt Sauls
Actual Vel: 3134 fps
Powder Wt: --

Remarks: Point of impact was on top of round No. 1. Entrance hole was enlarged 1-1/2 inches in diameter. Severe cracking was sustained around the top of the entrance hole.

Date: 1 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: 3500 fps
Powder Type: IMR 4350

Round No. 3
Projectile Caliber: 20mm FSP
Gunner: TSgt Sauls
Actual Vel: 3514 fps
Powder Wt: --

Remarks: Point of impact was on top of round No. 1. Entrance hole was 1-1/2 inches in diameter. The single-phase and three-phase inverters were 100 percent destroyed. Six wires in wiring harness were severed. Pilot's right foot would have been a 100 percent loss.

Date: 1 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: Standard
Powder Type: Standard

Round No. 4
Projectile Caliber: 14.5mm API
Gunner: TSgt Sauls
Actual Vel: 3339 fps
Powder Wt: --

Remarks: Point of impact was in the center of the third panel on the right side of the aircraft, nine inches below the crack. Entrance hole was one inch in diameter; 15 wires in the wiring harness were severed. The seat had a 1/2-inch-diameter hole on the right side and a 1/4-inch-diameter hole on the left side. Projectile was stopped on the left side of the fuselage by a structural member.

Date: 1 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: Standard
Powder Type: Standard

Round No. 5
Projectile Caliber: 14.5mm API
Gunner: TSgt Sauls
Actual Vel: 3322 fps
Powder Wt: --

Remarks: Point of impact was three inches above round No. 4. Entrance hole was one inch in diameter. Seat had one hole 1/2-inch in diameter, one hole 1/4-inch in diameter, and one hole 1/8-inch in diameter. Projectile was stopped by a sand bag used to hold down the pilot's seat.

Date: 1 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: Standard
Powder Type: Standard

Round No. 6
Projectile Caliber: 14.5mm API
Gunner: TSgt Sauls
Actual Vel: 3316 fps
Powder Wt: --

Remarks: The point of impact was three inches above round No. 5. Entrance hole was 1-1/4 inches x 1-1/2 inches. One piece 6 inches x 3-1/2 inches was removed from armor plate. Four holes 1/8-inch in diameter or less were in the seat, and the arm rest in the seat had one piece removed 2 inches x 3/4 inch behind the front of rest.

Date: 29 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: Standard
Powder Type: Standard

Round No. 1
Projectile Caliber: 20mm HEI
Gunner: TSgt Sauls
Actual Vel: No reading
Powder Wt: --

Remarks: Impact point was on the first panel on the right side of aircraft, 12 inches above lower leading edge and 5 inches in front of rear leading edge. Projectile was splattered on the surface of the armor. No visible damage was sustained.

Date: 27 Aug 69
Range: C-74L
Recorder: Lt Winger
Required Vel: Standard
Powder Type: Standard

Round No. 2
Projectile Caliber: 20mm HEI
Gunner: TSgt Sauls
Actual Vel: No reading
Powder Wt: --

Remarks: Impact point was 6 inches below round No. 1. No visible damage was sustained.

APPENDIX IV

LOADING TECHNIQUES

Preliminary firings were conducted in order to determine propellant loads needed for the required striking velocities in the test plan. These firings were conducted in an indoor range on Test Area A-22 Bay 9, Eglin AFB, Florida.

Initially, some difficulty was encountered in obtaining the required maximum velocities for each projectile type. In both the .30 caliber and .50 caliber cartridges, it was not possible to upload the cases to the required charges. Some common propellants were tested, but in all cases either not enough powder could be loaded or evidence of extreme over-pressures (i.e., cases jammed in chamber, blown-out primer) made it impossible to obtain satisfactory results.

In order to increase the propellant loads, firings were made using .50 caliber cases with the .30 caliber projectiles and 20mm cases with the .50 caliber projectiles. Special Mann barrels with increased chamber sizes for the proper caliber were used. The procedure for loading these barrels was to first position the projectile at the end of the chamber (beginning of the rifling), then insert the loaded case and the breech and firing lines.

TABLE IV-1. PRELIMINARY FIRING DATA

PROJECTILE CALIBER	LOAD (GRAINS)	VELOCITY (FPS)	POWDER	GUN SIZE CHAMBER/BORE	REMARKS
.30	50	2923	Standard 30.06	30/30	
.30	50	2906	Standard 30.06	30/30	
.30	50	2923	Standard 30.06	30/30	
.30	55	3101	Standard 30.06	30/30	
.30	55	3094	Standard 30.06	30/30	
.30	55	3094	Standard 30.06	30/30	
.30	56	3132	Standard 30.06	30/30	Maximum load
.30	56	3140	Standard 30.06	30/30	Maximum load
.30	54	3012	Standard 30.06	30/30	
.30	54	3026	Standard 30.06	30/30	
.30	48	2750	Standard 30.06	30/30	
.30	48	2744	Standard 30.06	30/30	
.30	45	2623	Standard 7.62	30/30	

TABLE IV-1. (CONTINUED)

PROJECTILE CALIBER	LOAD (GRAINS)	VELOCITY (FPS)	POWDER	GUN SIZE CHAMBER/BORE	REMARKS
.50	250	2768	IMR 4198	20/50	
.50	300	3117	IMR 4198	20/50	
.50	300	3121	IMR 4198	20/50	
.50	325	3310	IMR 4198	20/50	Maximum load
.50	250	2560	WC 870	20/50	
.50	220	2545	IMR 4895	20/50	
.50	225	2577	IMR 4895	20/50	
.50	230	2577	IMR 4895	20/50	
.50	235	2631	IMR 4895	20/50	
.50	240	2673	IMR 4895	20/50	
.50	245	2732	IMR 4895	20/50	
.50	250	2744	IMR 4895	20/50	
.50	220	3160	IMR 4831	50/50	
.50	225	3234	IMR 4831	50/50	
.50	230	2540	IMR 4831	20/50	
.50	235	2545	IMR 4831	20/50	
.50	235	2543	IMR 4831	20/50	
.50	250	2572	IMR 4831	20/50	
.30	50	2850	Standard 7.62	30/30	
.30	55	3094	Standard 7.62	30/30	
.30	60	3280	Standard 7.62	30/30	Case jammed in chamber after shot
.30	58	3217	Standard 7.62	30/30	Case jammed in chamber after shot

TABLE IV-1. (CONTINUED)

PROJECTILE CALIBER	LOAD (GRAINS)	VELOCITY (FPS)	POWDER	GUN SIZE CHAMBER/BORE	REMARKS
.50	235	2941	Standard .50 Caliber	50/50	
.50	235	2986	Standard .50 Caliber	50/50	
.50	235	2983	Standard .50 Caliber	50/50	
.50	240	3019	Standard .50 Caliber	50/50	
.50	245	3097	Standard .50 Caliber	50/50	
.50	250	3125	Standard .50 Caliber	50/50	Maximum load
.50	250	3140	Standard .50 Caliber	50/50	Maximum load
.50	240	3164	Standard .50 Caliber +5-Gr Shotgun	50/50	
.50	260	2699	IMR 4831	20/50	
.50	270	2717	IMR 4831	20/50	
.50	280	2824	IMR 4831	20/50	
.50	285	2834	IMR 4831	20/50	
.50	290	2821	IMR 4831	20/50	
.50	290	2873	IMR 4831	20/50	
.50	295	2896	IMR 4831	20/50	
.50	300	2903	IMR 4831	20/50	
.50	305	2951	IMR 4831	20/50	
.50	310	2941	IMR 4831	20/50	
.50	315	3044	IMR 4831	20/50	
.50	320	3037	IMR 4831	20/50	
.50	325	3045	IMR 4831	20/50	
.50	330	3086	IMR 4831	20/50	
.50	335	3132	IMR 4831	20/50	

TABLE IV-1. (CONCLUDED)

PROJECTILE CALIBER	LOAD (GRAINS)	VELOCITY (FPS)	POWDER	GUN SIZE CHAMBER/BORE	REMARKS
.50	340	3164	IMR 4831	20/50	
.50	345	3221	IMR 4831	20/50	
.50	350	3276	IMR 4831	20/50	
.50	355	3289	IMR 4831	20/50	
.50	360	3328	IMR 4831	20/50	
.50	365	3346	IMR 4831	20/50	
.50	365	3448	IMR 4350	20/50	
.50	365	3467	IMR 4350	20/50	
20mm FSP	250	2158	IMR 4350	20/20	
20mm FSP	275	2356	IMR 4350	20/20	
20mm FSP	300	2501	IMR 4350	20/20	
20mm FSP	325	2847	IMR 4350	20/20	
20mm FSP	365	3015	IMR 4350	20/20	
20mm FSP	375	3109	IMR 4350	20/20	
20mm FSP	400	3268	IMR 4350	20/20	
20mm FSP	425	3448	IMR 4350	20/20	
.30	150	3987	IMR 4350	50/30	
.30	100	3030	IMR 4350	50/30	
.30	125	3501	IMR 4350	50/30	
.30	115	3351	IMR 4350	50/30	
.30	110	3205	IMR 4350	50/30	
.30	105	3160	IMR 4350	50/30	
.30	112	3267	IMR 4350	50/30	
.30	112	3242	IMR 4350	50/30	

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11. SUPPLEMENTARY NOTES

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13. ABSTRACT

This report discusses the methodology used to conduct ballistic tests in support of an experimental armor system for the protection of aircrew members. The system was designed to protect crew members of high performance aircraft and was installed on an obsolete F-89J aircraft for destructive tests. Shots were fired with .30 caliber and .50 caliber AP-M2 and 20mm fragment simulating projectiles. Field firing records of all shots are contained in Appendix III. No analysis of the field data was made in this report.

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Materials evaluation						
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Personal protection						
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Ceramic armor						
Terminal ballistics						
Vulnerability						